



Original Research

# Perceived Effect of Socket Fit on Major Lower Limb Prosthetic Rehabilitation: A Clinician and Amputee Perspective



Shruti Turner, MSc <sup>a</sup>, Alison H. McGregor, PhD <sup>a,b</sup>

<sup>a</sup> Centre for Blast Injury Studies, Imperial College London, London, United Kingdom

<sup>b</sup> Sackler MSk Lab, Imperial College London, London, United Kingdom

## KEYWORDS

Amputation;  
Amputees;  
Artificial limbs;  
Prostheses and implants;  
Prosthesis fitting;  
Rehabilitation

**Abstract Objectives:** To determine the perspectives of amputees and rehabilitation clinicians on the effect of socket fit and issues caused by ill-fitting sockets throughout lower limb prosthetic rehabilitation.

**Design:** A survey was developed to identify rehabilitation factors and issues for prosthesis wearers and rehabilitation clinicians. Participants opted to participate in a further telephone interview.

**Setting:** Online and across the United Kingdom.

**Participants:** Lower limb prosthetic wearers and clinicians who are part of a lower limb prosthetic rehabilitation team (N=94).

**Interventions:** Not applicable.

**Main Outcome Measures:** A survey and an interview to measure the perceived effect of socket fit on lower limb rehabilitation.

**Results:** Issues related to socket fit were identified as the biggest factor affecting rehabilitation by 48.0% of amputees and 65.7% of clinicians. Amputee interviewees focused on the effect of fit on quality of life and the ability to complete daily tasks, whereas clinicians focused on the lack of widespread ability to adjust the socket and gait re-education.

**Conclusions:** Socket fit has a large effect on and is a large source of frustration to amputees and their clinical teams throughout rehabilitation. From the interviews, it became clear that the interpretation of socket fit is different for each person; thus, "socket fit" does not mean the same for all patients.

© 2020 The Authors. Published by Elsevier Inc. on behalf of the American Congress of Rehabilitation Medicine. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

*List of abbreviations:* NHS, National Health Service; PEQ, Prosthetic Evaluation Questionnaire; QoL, quality of life; UK, United Kingdom. Supported by the Royal British Legion.

Disclosure: none.

Presented to Centre for Blast Injury Studies, November 22, 2018, London, United Kingdom; and the International Society of Prosthetics and Orthotics, October 5-8, 2019, Kobe, Japan.

Cite this article as: Arch Rehabil Res Clin Transl. 2020;2:100059.

<https://doi.org/10.1016/j.arrct.2020.100059>

2590-1095/© 2020 The Authors. Published by Elsevier Inc. on behalf of the American Congress of Rehabilitation Medicine. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

The number of lower limb amputees in the United Kingdom (UK) has risen as a result of an ageing population and recent military conflicts.<sup>1</sup> Between 2014 and 2017, there was a 4.1% increase owing to diabetes,<sup>2</sup> and there were 355 lower limb amputations resulting from the Afghanistan conflict (2006-2014).<sup>3</sup>

This increased amputee population has focused interest in prosthetic design. The development of prostheses has been significant, from having no joints<sup>4,5</sup> to mechanical joints<sup>5</sup> and microprocessor controllers,<sup>6</sup> and from wood<sup>4</sup> to carbon fiber and lightweight plastics.<sup>7</sup> Conversely, in the UK, prosthetic socket rigidity has received less attention, despite its importance in rehabilitation and residuum health.<sup>8-11</sup> The socket is the point of load transfer from the body to the prosthesis and is a complex interface.<sup>8,9</sup> Although the design of prosthetic sockets has evolved with regard to shape, interface, suspension mechanisms, and materials, it remains a rigid case around the residuum for the majority of users in the UK.<sup>4,5</sup> Adjustable sockets, although available in some countries, are not commonplace in the UK. Progressing prosthetic design necessitates the optimization of socket fit, which is important for successful rehabilitation.

The socket-residuum interface is not ideal: bony prominences, soft tissue, and skin are subjected to high loading conditions in a hot and moist environment.<sup>9</sup> These should be considered in combination with other prosthetic factors (eg, alignment and suspension) when optimizing socket fit to avoid skin breakdown.

Socket fitting is an iterative process, dependent on the skills and experience of the prosthetist. Prosthesis users reported an average of 9 visits per year to their prosthetists, with 70% of socket or suspension mechanism related visits resulting from difficult residuum conditions.<sup>8,12,13</sup> The use of computer aided design and manufacturing has the potential to aid this process but uptake is limited<sup>8,14</sup> because of cost and a belief by some that technologies do not adequately replace experienced clinicians.

The core criteria for a well-fitting socket is patient comfort, documented using either the Prosthetic Evaluation Questionnaire (PEQ)<sup>15</sup> or Socket Comfort Score.<sup>16</sup> Although an important factor in an amputee's acceptance of the prosthesis, comfort ratings may be an unreliable measure.<sup>17</sup> Unreliability of socket comfort measures, daily changes of the residuum, and altered or lost residuum sensation lead to variation in the actions taken.

Many conditions result from poor socket fit,<sup>5,11,18</sup> affecting the residuum<sup>19-22</sup> and the rest of the body,<sup>8,10,18,23</sup> including skin breakdown, pressure sores, musculoskeletal overuse injuries, and osteoarthritis. These are believed to result from an inability to effectively load through the socket, thus affecting short- and long-term quality of life (QoL), physical and mental health,<sup>24</sup> preventing the prosthesis being worn, and restricting ambulation and function.<sup>25</sup>

Demet et al<sup>24</sup> assessed the QoL of amputees using the Nottingham Health Profile,<sup>26</sup> which has 2 parts: exploring experiences of distress and perceived health problems. There are no questions concerning the prosthesis, with outcomes focusing on self-reported QoL measures. Legro et al's<sup>11</sup> study assessed the importance of issues reported by lower limb amputees related to their prostheses using

the PEQ, followed by open-ended questions to further explore perspectives. Legro et al identified that prosthetic fit was highly important, with "fit of the socket with the residual limb" highlighted as 1 of 4 core themes and prevention of skin breakdown and residuum health noted as top priorities.

Understanding the effect of ill-fitting sockets reported by amputees who experience them first-hand and rehabilitation teams is important. It is expected that amputees and clinicians may perceive different factors to have a higher effect on rehabilitation. Amputees experience their own journey, whereas clinicians see many patients and may understand medical and logistical factors that amputees do not. This will enable research and development to target these issues and improve QoL.

This initial survey aims to understand the perceived effect of socket fit on lower limb rehabilitation, steering the direction of future qualitative and quantitative research to address key issues caused by ill-fitting sockets.

## Methods

### Design

A survey ([appendix 1](#)) approved by Imperial College London Joint Research Compliance Office was distributed as an initial inquiry into the perceived effect of socket fit on rehabilitation. Such information is not collected by common outcome tools (eg, PEQ, Socket Comfort Score). The survey was developed and tested with amputee rehabilitation physiotherapists initially owing to issues engaging active amputees.

The first questions focused on respondents' demographics. The survey then aimed to assess the effect socket fit is perceived to have on rehabilitation, beginning with a free text question to gather the uninfluenced perspectives of respondents before asking specifically about sockets. The free text question asked for up to 5 factors influencing rehabilitation, before being asked to identify which had the greatest influence. The following 2 questions were multiple choice regarding the main issues related to rehabilitation and the socket.

The aim of the interviews ([appendix 2](#)) was to seek the reasons underpinning the survey answers. Semistructured telephone interviews were chosen as individual perspectives were sought and minimized travel, enabling recruitment over a larger geographical area and facilitating greater participation.

A semistructured approach has been used within multidisciplinary clinical environments for studies involving different participant groups when aiming to discover individual perspectives in patients' own words.<sup>27</sup> This approach allows participants the freedom to talk with minimal interference within a structure that allows relevant information to be collected. Three open questions were asked regarding participant survey answers. Closed follow-up questions were asked for clarification or to direct participants towards the details sought. The interviewer aimed to keep their responses within the first 3, least directive, bands on Whyte's directive scale: (1) making encouraging

noises, (2) reflecting on interviewee remarks, and (3) probing on the interviewee's last remark.<sup>28</sup>

## Participant recruitment

To recruit lower limb amputee prosthesis wearers and rehabilitation teams for the study, an online survey link was distributed via e-mail to personal contacts in relevant clinical teams (prosthetists and physiotherapists), relevant charities (eg, Disability UK, Blesma), and on social media via Twitter, Facebook, and LinkedIn. Hashtags such as "#amputation," "#amputee," and "#prosthetics" were used to increase reach. Direct messages to amputee networks on Twitter and Facebook were also used. Completed paper copies were inputted into the online survey by the research team.

Inclusion criteria stated that participants must be 18 years or older, currently not taking medication that affected cognitive function, have a good understanding of written and spoken English, and be amputees using a prosthesis. Clinicians were required to be part of a lower limb prosthetic rehabilitation team.

Participants could provide contact details to participate in a telephone interview. Identifying details were extracted from the survey before analysis for anonymity.

## Consent and data collection

The survey was deployed online using Qualtrics,<sup>a</sup> a web-based survey tool, and on paper. Consent was collected with the presentation of the Participant Information Sheet and a checkbox before the survey.

A semistructured approach was taken for the telephone interviews (see [appendix 2](#)). Prompt questions were asked where appropriate to clarify areas of uncertainty and obtain further details. Interviews were recorded using a smartphone, before being transcribed and anonymized.

Participant answers were analyzed to ensure the assessment of perspectives using individuals' own words.

## Data analysis

Survey responses were analyzed using descriptive statistics to determine the perceived effect of socket fit for different demographics. The interviews were analyzed by a single researcher (S.T.) with a biomedical engineering background, supported by the senior author, based on the framework method's 6 core steps: transcription, familiarization, framework, coding, charting, and interpreting.<sup>27</sup> However, as the focus of the study was on socket fit, the framework was chosen based on these specifics rather than themes in the interview transcripts.

The interviews were transcribed manually, before being reread by the researcher, and a framework of analysis was determined. The categories chosen for the framework were (1) socket fit explicitly mentioned, (2) issues mentioned related to socket fit, and (3) issues not related to socket fit. Guidance was taken from the literature outlining the consequences of ill-fitting sockets to determine issues related to socket fit (eg, pressure sores, movement in the socket, pain in the residuum).<sup>19-23</sup> The details for each participant were tabulated, including their role, relevant survey answers, and key points from their interview answers. The table was used to interpret the themes and distinguish trends.

## Results

A total of 94 participants completed the survey, including 50 amputees and 44 rehabilitation clinicians ([tables 1 and 2](#)). Because of the broad inclusion criteria, amputees of all major lower limb levels participated with a variety of etiologies ([tables 1 and 3](#)). The clinicians were grouped into the following: physiotherapists, prosthetists, and others (2

**Table 1** Overview of the amputee survey and the telephone interview participants

Characteristics	Survey Participants, n=50	Interview Participants, n=10
Age, mean ± SD	47.38±14.96	53.7±12.55
Years since amputation, mean ± SD	11.07±11.44	6.53±5.29
Etiology, n (%)		
Vascular	8 (16)	3 (30)
Cancer	5 (10)	1 (10)
Trauma (any)	29 (58)	3 (30)
Blast injury	7 (14)	0 (0)
Road traffic accident	15 (30)	3 (30)
Other trauma	7 (14)	0 (0)
Other	8 (16)	3 (30)
Level of amputation, n (%)		
Transtibial	18 (36)	6 (60)
Knee disarticulation	1 (2)	0 (0)
Transfemoral	17 (34)	3 (30)
Hip disarticulation	1 (2)	0 (0)
Number of leg amputations, n (%)		
Unilateral	30 (60)	9 (90)
Bilateral	8 (16)	1 (10)

**Table 2** Overview of the clinician survey participants, including the number of each who participated in the telephone interviews

Job Role	Survey Participants	Interview Participants	Years of Experience in Role, Mean $\pm$ SD	Biggest Effect on Rehabilitation, %*	Biggest Frustration With Rehabilitation, %*	Biggest Frustration With Socket, %*
Total	44	8	12.97 $\pm$ 8.14	65.7	40.9	56.8
Physiotherapists	16	5	12.65 $\pm$ 8.18	62.5	37.5	62.5
Prosthetists	24	3	13.02 $\pm$ 8.09	66.7	41.7	50.0
Other	4	0	14.00 $\pm$ 7.11	50.0	50.0	66.7

NOTE. The percentage of socket fit related responses for each of 3 questions has been stated for the survey participants.

\* Percentage of answers related to socket fit.

occupational therapists, a biomedical engineer/prosthetist, and a prosthetic assistant practitioner).

There were 14 amputees serving in or veterans of the British Armed Forces, including 7 blast casualties; the remainder were non-military specific injuries. The results of this group were similar to the overall results and, therefore, the data were combined. Clinicians were asked for their primary employer, but it was difficult to use this information effectively because many worked in the private sector or were contracted to the military.

There were 30 amputees who identified as unilateral, but some individuals did not answer all aspects of their amputation descriptors and many did not indicate whether they were unilateral or bilateral, answering only the level of amputation or vice versa (see tables 1 and 3). No assumptions were made about gaps in the data. A summary of key survey results is outlined in tables 1, 2, and 3.

Of the 94 survey participants, 18 completed a telephone interview (table 4). The demographic spread of interviewees was representative of survey participants (see table 1). The interviews were coded for 3 categories: (1)

socket fit explicitly mentioned, (2) issues mentioned related to socket fit, and (3) issues not related to socket fit. Examples of issues related to socket fit were residuum pain and lack of knee mobility owing to the socket. Issues not related to socket fit included using public transport and access to benefits.

Analyzing the transcripts revealed specific issues for each demographic, but overarching themes relating to socket fit were clear: QoL and disparity between services. The latter affected the quality of socket fit and the former was a consequence.

### Quality of life and socket fit

The amputees' views focused on the effect on QoL and their ability to perform daily tasks, focusing on 2 aspects: (1) residuum volume fluctuation and (2) pain and discomfort. One amputee stated, "the nearest analogy...is wearing a shoe that doesn't fit. Never mind if it's a Jimmy Choo... If the shoe is too small or doesn't fit, it hurts. You

**Table 3** Overview of the amputee survey participants with a summary of responses to key questions

Characteristics	Participants, n	Biggest Effect on Rehabilitation, %*	Biggest Frustration With Rehabilitation, %*	Biggest Frustration With Socket, %*
Total	50	52.0	42.0	52.0
Etiology				
Vascular	8	50.0	37.5	25.0
Cancer	5	40.0	40.0	80.0
Trauma (any)	29	51.7	48.3	51.7
Blast injury	7	42.9	57.1	71.4
Road traffic accident	15	40.0	33.3	46.7
Other trauma	7	85.7	71.4	71.4
Other	8	62.5	25.0	37.5
Level of amputation				
Transtibial	18	31.6	26.3	30.0
Knee disarticulation	1	-	0.0	100.0
Transfemoral	17	47.0	47	41.2
Hip disarticulation	1	100	100	0
Number of leg amputations				
Unilateral	30	30.0	33.3	30.0
Bilateral	8	37.5	37.5	50.0

NOTE. The percentage of socket fit related responses for each of 3 questions has been stated for the survey participants.

\* Percentage of answers related to socket fit.

**Table 4** Overview of the clinician and amputee interview participants

Characteristics	Interview Participants, n	Biggest Effect on Rehabilitation, %*	Biggest Frustration With Rehabilitation, %*	Biggest Frustration With Socket, %*
Total	18	61.1	38.9	50.0
Clinician	8	50.0	37.5	50.0
Physiotherapists	5	40.0	40.0	40.0
Prosthetists	3	66.7	33.3	66.7
Amputees	10	70.0	40.0	50.0
Transtibial	6	66.7	16.7	33.3
Transfemoral	3	66.7	100.0	66.7
Unspecified	1	100.0	0.0	100.0

NOTE. The percentage of socket fit related responses for each of 3 questions has been stated for the survey participants.

\* Percentage of answers related to socket fit.

can't walk properly. It's very similar with socket fit." Similar themes were established by prosthetists: "each component of the limb is equally important, but the socket is the only one that gives an absolute 'no I can't use the prosthesis.'"

Volume fluctuation was an issue noted by clinicians. Physiotherapists mentioned volume fluctuation in relation to the effect on ambulation, specifically gait irregularities. The prosthetists mentioned this in the context of wanting adjustable sockets to compensate for residuum changes.

### Disparity in services and socket fit

A disparity between services was also perceived: compared to the National Health Service (NHS), private clinics had "better" technology and procedures. One of the amputees stated "I know that better quality, more efficient limbs are given to ex-servicemen and athletes. Why should I be second-class?" in the survey and interviewees described friends who have "better" service and sockets, because it is paid for privately. Clinicians noted the difference in the working environment: "I've a bit of a different colour, because I work privately our sockets are generally a bit better" and another noted the longer turnaround time for socket manufacture in the NHS.

Socket fit is highlighted by all, however. Although each talked about the same issue, the emphasis of their descriptions was different. The participants communicated their socket fit issues without defining the term. Thus, there is no indication that "good fit" means the same thing to everyone.

### Discussion

Socket fit is the main factor for amputees and clinicians affecting rehabilitation, a finding supported by Legro et al's study.<sup>11</sup> However, the specifics of socket fit remain ill defined. This study's survey responses address the perceived effect of socket fit on lower limb prosthetic rehabilitation, and the interviews begin to show the reasons behind the issues. The breakdown of amputation levels indicates that bilateral amputees have a worse experience with their sockets than unilateral amputees (see table 3). There is an increased perception among transfemoral

amputees that socket fit has a bigger effect on rehabilitation, compared with transtibial amputees. The literature shows that outcomes are less positive for higher-level amputations and those with multilimb deficits.<sup>29,30</sup> Those with multiple amputations or amputations at a higher level are generally less stable on their prostheses than transtibial, unilateral amputees owing to the increased change to their anatomy and gait. For this reason, it is important that these amputees are satisfied with and can load effectively through their prosthesis. This study indicates that the overall functionality of amputees may relate to the perceived effect of socket fit. This is something empirically known amongst clinicians. However, an evidence-base is yet to be established.

The results are similar across amputation causes. Given the unpredictability of blast and road traffic injuries and their known complexities, it is interesting to note that socket fit is not perceived to be a main factor. This may be because traumatic amputations are often a 2-stage process: first to salvage the limb and save the patient's life and another to create the residuum. However, it is expected that traumatic amputees have a higher risk of poor residuum quality resulting from associated tissue damage.

Comparing clinician and amputee perspectives (see tables 2 and 3), the survey indicates that clinicians believe socket fit and related issues have a larger effect on rehabilitation than amputees, with 17.7% more identifying it as the main factor. However, when asked about issues with rehabilitation and the socket itself, the perceptions of clinicians and amputees converge. This may be due to the difference in question: effect versus frustration. Clinicians have some objectivity in their work and see many amputees, whereas the amputees' answers are based on individual experience. Clinicians may have a wider understanding of the issues across a range of people and can thus identify trends.

The interviews allowed for exploration into the survey answers, with the perspectives of participants gained in their own words. Amputee interviewees framed their issues with socket fit in the context of the effect on their function and experience. Most did not mention socket fit explicitly but talked about known consequences of ill-fitting sockets (eg, pain, pressure sores, volume fluctuation).<sup>19,21-23</sup> The clinicians were divided in the specifics of their socket fit issues. Physiotherapists were concerned with gait re-



education and rehabilitation, identifying consequences of the socket fit as one of the main causes preventing gait re-education. Prosthetists, on the other hand, linked socket fit to the ability to adjust sockets. The different foci of the clinicians are likely the result of the specific roles they hold.

Money and resources in the private and military settings were noted to be higher than the NHS. Comparisons were made by NHS-treated amputees, between their own experiences and the military and Paralympians', both in terms of quality of prostheses and socket-related issues. The mentality of amputees going through rehabilitation influences the progress and success of the process.<sup>31</sup> Therefore, if these individuals believe that there are "better" solutions available elsewhere, it is more likely that they will not accept and persevere with the imperfections in their sockets. The interviews showed that all groups talked about "good socket fit." However, the interpretation is different for each individual. This introduces difficulties when trying to rectify ill-fitting sockets, because addressing issues for one may not solve issues for another (eg, comfortable sockets may not facilitate gait symmetry). The use of the same term does not guarantee that communication is clear, which may inhibit solving socket issues.

Although the current study pertains to the UK, comparisons with the international literature suggest that these results are not unique to amputees in the UK.<sup>11,13,32</sup> The fit of the socket is noted as a priority in Legro et al's<sup>11</sup> study and is supported by Pezzin et al's<sup>13</sup> study, in which nearly one-third of amputees expressed dissatisfaction with socket comfort.

### Study limitations

Given the nature of the survey questions, it may be that some issues are caused by others listed (eg, pain may be caused by a poor fit). The additional interviews aimed to compensate for the loss of information, although with a 19.1% conversion from survey to interview, many perspectives remained unheard. It is also possible to obtain differing statistics when interpreting free text responses: to categorize an issue as related to socket fit is dependent on how the descriptions are interpreted.

The interviewee population, although representative of the survey participants, is a self-select group and may have been most inclined to complete the interview as they have the strongest views. It must be considered when concluding that these case studies are likely to be some of the more extreme cases.

This study identifies the effect of socket fit on rehabilitation. However, the definition of socket fit is not explored in this study and, therefore, conclusions of what defines socket fit are still poorly understood.

### Future work

Only amputee prosthesis wearers and members of clinical rehabilitation teams were included in this study. It is important to gain an understanding of the entire amputation journey. Therefore, the perspectives of surgeons conducting the amputation procedures are vital to complement

the rehabilitation team and amputee perspectives to determine whether surgical technique influences socket fit and rehabilitation. It is also important to gather the perspectives of those involved with the wellbeing and mental health of the amputees through their recovery (eg, occupational therapists, psychiatrists), as they are often leading the rehabilitation teams and seeing patients in the clinic with socket issues.

Throughout the study, the term socket fit has been used. However, the interviews suggest that socket fit means something different to everyone and, therefore, investigation of contributing factors is required.

### Conclusions

Socket fit and related issues are perceived to be a large factor contributing to frustration among amputees and their clinical teams during rehabilitation. The interpretation of socket fit, although similar within each of the defined groups (amputee, physiotherapist, and prosthetist), seems to have different specific meanings to each individual. The results of this study lead to questions that must be addressed regarding the specifics of socket fit, owing to the continued lack of a standardized definition.

### Supplier

- a. Qualtrics.

### Corresponding author

Shruti Turner, MSc, Room 202, Sir Michael Uren Hub, Imperial College London, White City Campus, 80-92 Wood Lane, London W12 0BZ E-mail address: [s.turner17@imperial.ac.uk](mailto:s.turner17@imperial.ac.uk).

### Appendix 1

#### Questionnaire for Amputee Volunteers

1. Please state your age in years.
2. What level of lower limb amputation do you have? (tick all that apply)
  - a. Unilateral/bilateral
  - b. Transtibial/knee disarticulation/transfemoral/hip disarticulation
3. Do you have any upper limb amputations?
  - a. Yes (please give details)
  - b. No
4. In years and months, how long ago did you have your amputation(s)?
5. Please select the statement that best describes you.
  - a. I am currently serving in the Armed Services
  - b. I am a veteran of the Armed Services
  - c. I have never been employed by the Armed Services
6. [If a or b selected in Q4] Please state the years you were serving?
7. What was the cause of your limb loss?

- a. Vascular
  - b. Cancer
  - c. Trauma
  - d. Other (please specify)
8. [If c selected in Q7] Please could you specify the type of trauma?
    - a. Blast injury
    - b. Road Traffic Accident
    - c. Other (please specify)
  9. Please state the main issues that you experienced during your prosthetic rehabilitation? (Up to 5)
  10. Which of these issues do you feel has had the biggest impact on your rehabilitation?
  11. What frustrates you most about your rehabilitation?
    - a. Wound complications
    - b. Time to get socket
    - c. Socket fit
    - d. Time with clinical rehab team
    - e. Lack of continuity in services
    - f. Pain (please specify where)
    - g. Other (please specify)
  12. What frustrates you most about your socket?
    - a. Poor fit
    - b. Too heavy
    - c. Limb gets hot
    - d. Limb gets sweaty
    - e. Other (please specify)
  13. What is the main thing that you would want to change about your socket?
  14. If you are willing to participate in an approximately 30-minute telephone interview relating to this research, please let us know the following details:
    - a. Name
    - b. Contact number
    - c. E-mail address

#### Questionnaire for Clinical Volunteers

1. What is your professional role?
  - a. Prosthetist
  - b. Physiotherapist
  - c. Occupational Therapist
  - d. Other (please specify)
2. Which organisation is your primary employer?
  - a. British Armed Forces
  - b. National Health Service
  - c. Other (please specify)
3. How many years of professional experience do you have working with amputees in your role?
4. Please state the main issues that you experience during prosthetic rehabilitation? (Up to 5)
5. Which of these issues do you feel has the biggest impact on the rehabilitation of amputees?
6. What frustrates you most about the rehabilitation process?
  - a. Wound complications
  - b. Time for amputee to get socket
  - c. Socket fit
  - d. Lack of time with amputee
  - e. Lack of continuity between in services
  - f. Other (please specify)

7. What frustrates you most about the socket itself during the rehabilitation process?
  - a. Poor fit
  - b. Too heavy
  - c. Limb gets hot
  - d. Limb gets sweaty
  - e. Other (please specify)
8. Did you have access to anything specific that helped you fulfil your role?
9. What would you have liked to have access to in order to help you in your role?
10. If you are willing to participate in an approximately 30minute telephone interview relating to this research, please let us know the following details:
  - a. Name
  - b. Contact number
  - c. E-mail address

## Appendix 2

### Interview Questions for Amputee Volunteers

1. In your questionnaire you mentioned that you felt \_\_\_\_\_ had the biggest impact on your function. Please could you describe what you mean in more detail?
  - a. Could you explain why this is a problem for you?
  - b. How do you think it limits what you want to do?
2. In your survey you said \_\_\_\_\_ was your biggest frustration with your rehabilitation. Please could you explain what you mean in more detail?
3. In your survey you said that \_\_\_\_\_ was your biggest frustration with your socket. If a new technology was developed to be able to solve this problem would you be willing to try it?
  - a. If no, please could you explain why?
  - b. If yes, what would stop you wanting to adopt the new technology into your everyday routine?

### Interview Questions for Clinical Volunteers

1. In the survey you state that you felt \_\_\_\_\_ had the biggest impact on prosthetic rehabilitation. Please could you describe what you mean in more detail?
  - a. Could you explain why this is a problem?
  - b. Does it stop you doing something that you would otherwise?
2. In the survey you stated that \_\_\_\_\_ was your biggest frustration during rehabilitation. Please could you explain what you mean in more detail?
3. [If problem identified as the main impactor on rehabilitation is not related to socket fit] In the survey you stated that \_\_\_\_\_ was your biggest frustration relating to the socket itself during rehabilitation. If a new technology was developed to be able to help solve this problem would you be willing to try it?
  - a. If no, please could you explain why?
  - b. If yes, what would stop you wanting to adopt a new technology into your routine practice?

## References

1. Ahmad N, Thomas GN, Gill P, et al. Lower limb amputation in England: prevalence, regional variation and relationship with revascularisation, deprivation and risk factors. A retrospective review of hospital data. *J R Soc Med* 2014;107:483-9.
2. DiabetesTimes. Lower limb amputations up by almost 20% says Diabetes UK. Available at: <https://diabetestimes.co.uk/lower-limb-amputations-up-by-almost-20-says-diabetes-uk/>. Accessed February 8, 2019.
3. Ministry of Defence. Request list of lower limb amputations performed on UK military who served in Afghanistan. Available at: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/628173/2017-02229.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/628173/2017-02229.pdf). Accessed February 8, 2019.
4. History of the Great War. In: Macpherson WG, Bowlby AA, Wallace C, et al., editors. *Medical Service, Surgery of the War*. London: His Majesty's Stationery Office; 1922. p 460-98.
5. Marks GE. *Manual of artificial limbs: artificial toes, feet, legs, fingers, hands, arms, for amputations and deformities, appliances for excisions, fractures, and other disabilities of lower and upper extremities, suggestions on amputations, treatment of stumps*. Berkeley, CA: A.A. Marks; 1905.
6. Blatchford. *Understanding Microprocessor Knees: Orion3 MPK*. Available at: <https://www.blatchford.co.uk/prosthetics/microprocessor-knees/orion3-mpk/>. Accessed August 14, 2018.
7. OttoBock. *The Genium - Microprocessor Knee*. Available at: [https://www.ottobock.co.uk/prosthetics/lower-limb-prosthetics/prosthetic-product-systems/genium\\_above\\_knee\\_system/](https://www.ottobock.co.uk/prosthetics/lower-limb-prosthetics/prosthetic-product-systems/genium_above_knee_system/). Accessed August 14, 2018.
8. Dickinson AS, Steer JW, Woods CJ, et al. Registering methodology for imaging and analysis of residual-limb shape after transtibial amputation. *J Rehabil Res Dev* 2016;53:207-18.
9. Dickinson AS, Steer JW, Worsley PR. Finite element analysis of the amputated lower limb: a systematic review and recommendations. *Med Eng Phys* 2017;43:1-18.
10. Hagberg K, Branemark R. Consequences of non-vascular transfemoral amputation: a survey of quality of life, prosthetic use and problems. *Prosthet Orthot Int* 2001;25:186-94.
11. Legro MW, Reiber G, del Aguila M, et al. Issues of importance reported by persons with lower limb amputations and prostheses. *J Rehabil Res Dev* 1999;36:155-63.
12. Haggstrom EE, Hansson E, Hagberg K. Comparison of prosthetic costs and service between osseointegrated and conventional suspended transfemoral prostheses. *Prosthet Orthot Int* 2013;37:152-60.
13. Pezzin LE, Dillingham TR, MacKenzie EJ, et al. Use and satisfaction with prosthetic limb devices and related services. *Arch Phys Med Rehabil* 2004;85:723-9.
14. Saunders CG, Foort J, Bannon M, et al. Computer aided design of prosthetic sockets for below-knee amputees. *Prosthet Orthot Int* 1985;9:17-22.
15. Legro MW, Reiber GD, Smith DG, et al. Prosthesis evaluation questionnaire for persons with lower limb amputations: Assessing prosthesis-related quality of life. *Arch Phys Med Rehabil* 1998;79:931-8.
16. Hanspal RS, Fisher K, Nieveen R. Prosthetic socket fit comfort score. *Disabil Rehabil* 2003;25:1278-80.
17. Hafner BJ, Morgan SJ, Askew RL, et al. Psychometric evaluation of self-report outcome measures for prosthetic applications. *J Rehabil Res Dev* 2016;53:797-812.
18. Levy SW. Skin problems of the leg amputee. *Prosthet Orthot Int* 1980;4:37-44.
19. Bouten CV, Oomens CW, Baaijens FP, et al. The etiology of pressure ulcers: skin deep or muscle bound? *Arch Phys Med Rehabil* 2003;84:616-9.
20. Ibbotson SH, Simpson NB, Fyfe NC, et al. Follicular keratoses at amputation sites. *Br J Dermatol* 1994;130:770-2.
21. Lyon CC, Kulkarni J, Zimerson E, et al. Skin disorders in amputees. *J Am Acad Dermatol* 2000;42:501-7.
22. Meulenbelt HE, Geertzen JH, Dijkstra PU, et al. Skin problems in lower limb amputees: an overview by case reports. *J Eur Acad Dermatol Venereol* 2007;21:147-55.
23. Gailey R, Allen K, Castles J, et al. Review of secondary physical conditions associated with lower-limb amputation and long-term prosthesis use. *J Rehabil Res Dev* 2008;45:15-29.
24. Demet K, Martinet N, Guillemin F, et al. Health related quality of life and related factors in 539 persons with amputation of upper and lower limb. *Disabil Rehabil* 2003;25:480-6.
25. Farrokhi S, Mazzone B, Eskridge S, et al. Incidence of overuse musculoskeletal injuries in military service members with traumatic lower limb amputation. *Arch Phys Med Rehabil* 2018;99. 348-54.e1.
26. Nottingham Health Profile. *J Orthop Trauma* 2006;20:S71.
27. Gale NK, Heath G, Cameron E, et al. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med Res Methodol* 2013;13:117.
28. Britten N. Qualitative interviews in medical research. *BMJ* 1995;311:251-3.
29. Amtmann D, Morgan SJ, Kim J, et al. Health-related profiles of people with lower limb loss. *Arch Phys Med Rehabil* 2015;96:1474-83.
30. Penn-Barwell JG. Outcomes in lower limb amputation following trauma: a systematic review and meta-analysis. *Injury* 2011;42:1474-9.
31. Horgan O, MacLachlan M. Psychosocial adjustment to lower-limb amputation: a review. *Disabil Rehabil* 2004;26:837-50.
32. Van der Linde H, Hofstad CJ, Geertzen JH, et al. From satisfaction to expectation: the patient's perspective in lower limb prosthetic care. *Disabil Rehabil* 2007;29:1049-55.