On physical functioning after pediatric burns
Disseldorp, Laurien Maria

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SUMMARY

Objectives
The overall aim of this dissertation is to gain insight into physical functioning after pediatric burns in the Netherlands. Beyond that, as part of a broader line of research, it is intended to support clinical practice in its efforts to assist patients in a timely and optimal physical recovery. This dissertation provides a compilation of results of studies on functional independence and physical fitness in children and adolescents after burn injury in the Netherlands.

The most important aims of the separate chapters were to:
• Determine functional independence throughout the first six months after pediatric burn injury
• Review the international literature in order to provide insight into physical fitness in people after burn injury and the effects of exercise programs
• Introduce the rationale and methods of a multidimensional study on physical fitness, physical activity, health-related quality of life and fatigue in children and adolescents after pediatric burns in the Netherlands
• Present the results on anthropometry, muscular strength and aerobic capacity up to five years after pediatric burns

Main findings
CHAPTER 2 focused on the level of functional independence, i.e. the performance of tasks of daily living without help/assistance from a person or device, in children with burns in the short term. More specifically, functional independence was determined on 18 items in the domains of self-care, mobility and cognition using the WeeFIM® instrument. Assessment took place at approximately two weeks, three months and six months post burn during either hospitalization or an already planned follow-up appointment. Subjects in this study were 119 pediatric patients (0.5-16 years) who had been admitted to a Dutch burn center for at least 24 hours. Inclusion rate was 86%, but in the course of the study subjects were lost to follow-up. At two weeks post burn 117 children were assessed, 22 of which showed affected functional independence in comparison to American norm values. 68 children were assessed at three months post burn and 38 at six months post burn. At both these time points, nine children (7.6% of the total study population) showed affected functional independence. Four children showed affected functional independence at all three assessments. Three of them had extensive burns; the other child’s low level of independence, however, was not due to burn injury but to cultural influence. The subgroup with burns >10% TBSA relatively accounted for the most affected children at each time of assessment. The study population showed significant improvement in WeeFIM® scores between two weeks post burn and six months post burn. The WeeFIM® instrument was found to be a feasible measure and sensitive to change in this study; nevertheless there were drawbacks to its use in this specific setting and population. To conclude, burn injury impacts functional independence in the short term, but at three months post burn the majority of children demonstrate adequate functional independence for their age. It is, however, important to keep an eye on those who tend to fall behind to prevent difficulties later in life.
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The next chapters, i.e. chapters 3, 4 and 5, focused on longer term outcomes and on capacity rather than daily life performance. The central theme in these chapters is physical fitness. Physical fitness is considered an important measure of health, as a good level of fitness is related to lower risk of illness and an improved quality of life\(^1\). **CHAPTER 3** comprised a systematic review of the burn literature on physical fitness, aiming 1) to gain insight into physical fitness in both children and adults after burn injury and 2) to present an overview of the effectiveness of exercise training programs in improving physical fitness after burns. Inclusion criteria were objective measurements and quantitative data on both the study population and the control group. Eleven studies were included and assessed on methodological quality: six studies for the first aim and nine for the second, as four studies were included in both parts of the review. The five components of health-related physical fitness as defined by Caspersen, i.e. body composition, muscular strength, muscular endurance, cardiorespiratory endurance and flexibility\(^2\), were used as a framework to structure results. Three main conclusions were drawn: 1) children and adults with extensive burns score worse than non-burned controls on all five components of physical fitness; 2) burn patients who participated in an exercise training program improved more on all components than burn patients without this specific training; and 3) although this knowledge is highly relevant, it is also very incomplete. The number of studies was limited and the number of institutes that had published on this topic was even smaller, as nine out of the eleven studies originated from the same institute. But above all, the incompleteness was due to great similarities in the included studies. In the comparison of physical fitness between burned and non-burned subjects, five out of six studies included children, all with very extensive burns (mean % TBSA range: 53.5-58.8). This is an exceptional selection of pediatric burn patients, considering both the low prevalence and the associated physiological consequences of such extensive burns, which makes the findings of the review not generalizable to the general, and in this case: Dutch, pediatric burn population. Besides the extent of burn, time post burn was a factor: all measures were done at six and nine (and in one study: twelve) months post burn, which is relatively short-term considering the severe physiological impact plus the long period of bed rest following such extensive burns.

To fill the hiatus in current knowledge that was uncovered in the review and to put physical fitness in context, a cross-sectional study was set up. **CHAPTER 4** described the rationale, design and methods of this study, which in addition to multiple physical fitness measures also comprised measures of physical activity, health-related quality of life (HRQoL) and fatigue. The multidimensional design was chosen because it provides a more comprehensive view on physical functioning after pediatric burns. This was illustrated in a conceptual model with physical fitness, physical activity, HRQoL and fatigue as the central themes, also including personal and environmental factors and burn characteristics. An overview of how these constructs are operationalized in the study was presented in chapter 4. The outcomes of the study would enable an exploration of both interrelations between the central themes and associations with burn characteristics. The study aimed at longer term outcomes in Dutch pediatric burn patients and the design paper emphasized that inclusion of children and adolescents with a great diversity in age (6-18 years), extent of burn (≥10% TBSA) and time post burn (0.5-5 years) was aimed for, in order to obtain a fair representation of the population. Furthermore, the design paper introduced the use of a mobile exercise lab for data collection, to increase the feasibility of the study and to minimize inconvenience for participation.
The study as described in chapter 4 has been completed and chapter 5 described a selection of the results of physical fitness variables: anthropometrics, muscular strength and aerobic capacity. 24 subjects were included, with an inclusion rate of 56.8%. The subjects varied in age from 6 to 18 years, in extent of burn from 10% to 41% TBSA and in time post burn from 1 to 5 years. Subjects’ scores were compared with Dutch age- and sex-matched norm values and calculated to Z-scores for all variables. For anthropometry, body height and weight, waist circumference and skinfold thickness were measured and, subsequently, BMI values and total skinfold thickness were calculated. No differences between subjects and norm values were seen in the data. Muscular strength was measured with a hand-held dynamometer, applied in elbow and knee flexion and extension, shoulder abduction and grip strength. On none of these variables were group means significantly different from the norm but, regarding individual scores, seven subjects scored significantly low on at least one strength variable. Lastly, aerobic capacity was measured using a graded exercise test, with VO$_{2\text{peak}}$ [mL·min$^{-1}$] and VO$_{2\text{peak}}$ per kilogram [mL·kg$^{-1}$·min$^{-1}$] as primary outcome parameters. All subjects completed the test without complications, but two subjects were excluded from analyses because criteria for maximal effort were not reached. The mean results of the 22 subjects did not significantly differ from the norm, but one subject scored significantly below the norm on VO$_{2\text{peak}}$ and one other subject scored significantly below the norm on VO$_{2\text{peak}}$ per kilogram.

Despite some individual deficits, our data showed adequate group levels of anthropometric measures, muscular strength and aerobic capacity for children and adolescents at 1-5 years after burns. Our data did not show trends indicating that either extent of burn or time post burn was associated to muscular strength or aerobic capacity outcomes.

The finding that moderate to severe pediatric burns do not necessarily affect physical fitness in the long term is a relevant addition to the knowledge on physical fitness after pediatric burns, since earlier studies had all concluded that physical fitness was affected during the first year after extensive burns. We suggested that these differences can be largely attributed to the fact that in our population more time had elapsed between burn injury and assessments, i.e. more time for physical recovery. Moreover, we like to emphasize the important role physical activity can play in the restoration of fitness after burns. Note that it is possible that specifically children interested in sports and an active, healthy lifestyle were inclined to participate in this study. Altogether, the results emphasize the strong resilience that many children show after burns.

In conclusion, this dissertation showed that children’s functional independence mostly returns to norm levels within 6 months post burn and that their physical fitness, measured between 1 and 5 years post burn, is quite similar to non-burned peers. Although these outcomes were adequate for the majority of Dutch children and adolescents after burns, there is an important minority that displays affected physical functioning that we may not overlook. All in all, it is yet unknown whether physical fitness is affected in pediatric burn patients with less extensive burns and/or at a longer period post burn. The current paper therefore aims to describe anthropometry, muscular strength and aerobic capacity in Dutch children and adolescents with a wide range of burn characteristics, also in comparison to norm values of non-burned peers.
GENERAL DISCUSSION

In this final section of the dissertation the included studies and findings will be discussed. Methodological considerations, a broad clinical message and subsequent directions for future research will be addressed.

Challenges in burns research

Although burn research on functional outcome is highly clinically relevant, it is still in its infancy and often hampered by, for example, small sample sizes and heterogeneous groups. In the Netherlands, too, we encounter several complications to set up large and high quality studies to provide conclusive evidence. Primarily, the sample sizes are generally small, because in this small and highly developed country, we see a relatively small number of burn patients. This is amplified by low inclusion rates, since a part of these burn patients cannot participate due to comorbidity or mental issues, they may not participate in a study because they participate in another study, or they do not want to participate in research as they have been through enough already.

Secondly, possibilities for statistical analyses are limited because (the already small sample of) burn patients form a very heterogeneous group, for instance in age, etiology and extent of burn. Together this hampers conclusive statements on the effect of a burn injury. Besides, each individual responds differently to a certain thermal impact and, when studying physical outcomes after burns, one should keep in mind that those are also influenced by psychological issues, social concerns and subjective experiences.

The potential problem of small sample sizes was dealt with in the planning of the clinical studies (chapters 2 and 5), and this resulted in satisfactory inclusion rates and sample sizes. The issue was partly tackled through organizing multicenter studies, including all Dutch burn centers. In case of the WeeFIM® study inclusion took place within the burn center and a long inclusion period was chosen to optimize sample size. Further, the WeeFIM® study had as main advantage that assessments were done during already planned appointments. The fact that participation did not take extra effort and could improve the monitoring of the child’s functioning, probably contributed to the inclusion rate of 86.6%. On the contrary, the cross-sectional fitness-study (chapters 4 and 5) did require extra effort from participants and parents, and therefore we were content with the inclusion rate of 56.8%. The use of a mobile exercise lab has almost certainly contributed positively to this inclusion rate, as was aimed at. The main advantages were that participants did not have to invest effort, time or money in travelling (to the burn center in Groningen, for example) for the measurements. Together with the factor that the assessments would take place at home at a convenient date and time for the participant, this was expected to reduce the threshold to participation and thus increase inclusion rate. Further, use of the mobile exercise lab added a unique element to the study. Lastly, potential participants were contacted first by members of the burn center staff, which may have contributed to their trust and the notion of the importance of the study.
Another challenge in burn research is that it seems susceptible to selection bias. In chapter 5 the possibility was mentioned that in particular the fittest children felt inclined to participate in the fitness study. Regarding all burn studies, it would be imaginable that the most heavily burned patients either refused to participate for they had been through enough already, or otherwise felt inclined to participate to gain a possible benefit or to find out whether something is ‘still wrong’. Information on selection bias is critical to indicate whether the study sample represents the population of interest, and should be taken into account when drawing conclusions on the findings. Non-response analyses is a tool to uncover selection bias on included subject characteristics like age, extent of burn or time post burn. Therefore, a non-response analysis was performed in chapter 5.

Furthermore, it is remarkable that, as pointed out in chapter 3, a large part of international burn research so far had focused on a small part of the population: people with exceptionally extensive burns. On the one hand, this seems tenable since more extensive burns have a larger and longer persisting impact, and thus knowledge and clinical support are very much needed to overcome difficulties in these patients. On the other hand, the remarkable fact that little is published about the recovery of patients with minor burns, gives the odd impression that the largest part of the burn population receives the least attention. Oppositely, Finlay et al. described that minor burn patients are being studied, but are often lost to follow-up.\textsuperscript{4} They proved that in their sample (16-66 years, <1-10% TBSA) the non-attendance at follow-up was not random, but most likely in younger people and related to a good recovery.\textsuperscript{4} The same ‘loss to follow-up’ was encountered in the WeeFIM®-study (chapter 2), mainly in the subgroups with burns <10%, because children who showed good recovery did not need follow-up visits.

\textit{Figure 1. The mobile exercise lab in which all physical fitness assessments took place}
and were, consequently, not assessed anymore. This ‘missingness’ hampers analysis of recovery after minor burns worldwide. The results of this dissertation contribute to current knowledge on outcomes after minor and moderate pediatric burns, and hopefully encourage other institutes to publish data on this large but under-published group of patients.

**Methodological considerations**

Besides the abovementioned population-related challenges in burn research, there are general methodological considerations about the clinical studies. Firstly, the designs will be discussed. Whereas the prospective cohort design used in the WeeFIM®-study (chapter 2) is quite strong, the cross-sectional design of the fitness-study (chapter 5) has some features that should be kept in mind in the interpretation of the results. Primarily, in a cross-sectional study the measurement is a snapshot: you measure only once at a certain time point that can be influenced by environmental and personal factors on that day. Further, the outcomes do not tell us anything about how the subject got to this level of functioning, or what he/she does in daily life. Was functioning ever affected? Has functioning improved due to time or due to training? Do these subjects need and use their physical capacities in daily life? Measures for physical activity, HrQoL and fatigue were included in the study to provide a more comprehensive view of the current situation. The abovementioned questions pointed at shortcomings of capacity assessment, yet measuring actual performance has its limitations as well. An illustrative example from the WeeFIM®-study: there was a risk of underestimation of functional independence during hospitalization, because inpatients could not accomplish several tasks, regardless of their physical capability, due to environmental restrictions in the burn center. However, note that these issues are inherent to clinical outcome research rather than limitations of the studies.

Secondly, considering data analyses, the use of norm values is subject to discussion. In both chapter 2 and chapter 5 no control group was measured for comparison between burned and non-burned peers. It might however seem somewhat ironical, since the inclusion and assessment of a control group was a requirement for inclusion of studies in the review (chapter 3). Instead, we deliberately used norm values from the literature and collected our data according to the same protocols and instruments. This was considered the most reliable and representative option since the used norm values were based on a larger group of children of each age than we could possibly have included and assessed ourselves. Apart from the use of norm values, there are some remarks to the norm values that were used for comparison. Firstly, in the norm values for both muscular strength and the WeeFIM®, strong fluctuations exist between age categories, despite the fact that they were based on many subjects. For example, the strength norm for knee flexors for 12 year old girls is 221N and for 13 year olds 301N, for 15 year old girls 282N and for 16 year olds 336N. The WeeFIM® norms were smoothed out before use. Secondly, while in the fitness-study only up-to-date and matched Dutch norm values were used, for the WeeFIM®-study Dutch norms were not available. Instead, the USA-norms as supplied with the instrument were used, risking influence of cross-cultural differences. Altogether, this emphasizes the importance of reliable norm values to enable a meaningful comparison of populations in clinical research. There is thus a need for reliable and widely accessible national norm data on many clinical outcome measures.
Restoration of physical functioning after burns

A certain decrease in physical functioning is inevitable after burns, but for this to persist in the long term is highly undesirable. Physical functioning is namely of major individual importance after burn injury in many areas of life. In addition, it is of societal and economic importance that burn patients optimally recover and achieve a full level of functioning, in order to enhance their societal contributions, for example by occupational activities, and to prevent health problems later in life. It is thus of great importance to restore physical fitness and functioning after burn injury to avoid long-term difficulties, especially so for pediatric patients since they have a whole life ahead of them.

For all people, physical activity is essential to acquire and maintain an adequate level of physical functioning. However, increasing levels of physical inactivity are seen worldwide. To illustrate this point: the World Health Organization reported that 80% of the world’s adolescent population is insufficiently physically active. As a consequence, promotion of physical fitness and physical activity in daily life has expanded considerably over the past years. Also in health care, physical activity is increasingly applied under the slogan ‘exercise is medicine’ and active rehabilitation has become widely accepted.

In burn care and rehabilitation ‘exercise is medicine’ indeed, as physical activity proved to improve physical fitness in patients with burns. Although the approach is gaining ground, physical activity should be applied more widely in burn rehabilitation than it currently is.

Figure 2 shows three hypothetical scenarios of the evolution of physical functioning in burn patients, compared to a non-burn scenario, and depicts possible gains through physical activity in the restoration of physical functioning after burns. Note that all burn-scenarios show a sudden decline in physical functioning, due to (the combination of) the pathophysiological consequences of the injury and the prolonged inactivity. If no effort is made to prevent the decline or to restore physical functioning later on, physical functioning decreases further following the negative spiral of deconditioning, or in the case of pediatric burns, the natural development is disturbed and a catch-up never occurs. Such is depicted in scenario 1, the lower line in Figure 2: the burn patient waits for the wound to heal and pulls away from activities in order not to put any more burden on the body and/or scars (which has an adverse effect). This might result in disability.

In scenario 2 there is no special attention for physical activity, though the burn patient re-integrates in society quite well. By resuming daily activities like school, play, hobbies, household, walking and cycling for transport, etc., the body is somewhat challenged and trained. Physical functioning improves gradually to a level that is sufficient for, but also limited by, this person’s daily activities. This results in suboptimal outcome in terms of health and future perspectives, as physical functioning is thus restricted by the inactive, more sedentary lifestyle as currently predominant in highly developed countries.

In scenario 3, in contrast, there is a focus on physical activity after burns, through which restoration of functioning is both accelerated and optimized. Presumably, the positive effects are threfold as physical activity could be effective to A) limit the deterioration of physical functioning shortly after burns; B) advance the restoration of functioning; and C) maintain the level of physical functioning on the longer term. These stages correspond with the frames in Figure 2.
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Frame A shows that the deterioration of physical functioning has come to a halt much earlier in scenario 3 than in the other scenarios. Deconditioning is limited by early intervention, i.e. mobilization and activation initiated already during hospitalization (before wound closure is complete) as soon as the patient is able to manage.

Frame B shows that physical activity after burns increases the slope of the improvement in physical functioning as well as the end result. Furthermore, the sooner one starts, the sooner a certain rehabilitation goal can be attained.

Frame C emphasizes the long-term importance of an optimal recovery of (pediatric) burns, hence it contains the ‘healthy aging’-perspective of this dissertation. This part of the figure is based on a similar figure from the WHO-report by Kalache & Kickbush. They suggested that a good level of functional capacity, a term synonymous with fitness, during early life can contribute to maintaining function and independence and prevents disability later in life. Thus, in scenario 3 the solid physical basis has made the system more robust which slows down the rate of deterioration of functioning at older age, whereas in the other scenarios a suboptimal level resulted in faster-than-general decline at older age that departed from an already lower level of functioning.

**Figure 2. Hypothetical scenarios of physical functioning after burns, depicting a threefold gain of physical activity.**

**Scenario 1:** Patient remains inactive after burns, pulls away from activities. **Scenario 2:** Patient fully reintegrates; functioning is sufficient for, but limited by daily activities. **Scenario 3:** The physically active patient shows faster restoration of functioning, an optimal end result, and the level of functioning is better maintained/preserved with aging.

To keep the emphasis on the essence of the concept and for clearness, the figure is kept simple; e.g. only three out of many possible scenarios are depicted, the development of physical functioning is drawn as a smooth curve and the proportions of the time frames are not realistic.
On top of all the physical benefits, it is likely that the psychosocial domain gains from physical activity as well. Physical activity is known to positively effect HrQoL and mental well-being\textsuperscript{21,22}, and the experience of improving physical functioning could improve the patients self-esteem, body-esteem and faith in future perspectives.

Besides the plead for the importance of physical functioning and physical activity, it must be mentioned that physical functioning is not the only relevant outcome after burns and that physical activity is not a holy grail. Yet, these issues deserve to be highlighted, as this is the first dissertation in this research line and because the perspective is gaining ground in both (international) research and clinical practice.

Clinical implications

Implications for clinical practice from this dissertation are mostly indirect yet recognizable. The used outcome measures have not (yet) been implemented into clinical practice in the Dutch burn centers. The WeeFIM® instrument is not used anymore, whereas the set of fitness assessments is currently applied in a longitudinal study and time will tell whether (some of) these assessments will find their place in clinical practice after that.

Regardless of permanent clinical implementation, both studies are deemed to have enlarged awareness of functional independence and physical fitness among clinicians. This is an important step, for the studies and results in this dissertation then serve as a stepping stone for further development in this field in both research and clinical practice. The multidisciplinary functional approach is not standard practice, since burns were originally a surgical specialty, but it is evidently upcoming. Over the last years, these developments have moved towards a comprehensive approach incorporating the ICF-model: the International Classification of Functioning, Disability and Health.\textsuperscript{23} The ICF conceptualizes functioning using the components ‘body functions and structures’, ‘activity’, and ‘participation’, that are in a complex, dynamic interaction with health status and contextual factors (both environmental and personal). Principles from the ICF-model are fundamental for the current research line, and thus for this dissertation. The ICF has recently been applied in other burn outcome research as well.\textsuperscript{3,24-26} In clinical practice in the Netherlands, the ICF-principles currently are increasingly applied, providing a framework directing acute care, rehabilitation and after care for patients with burns towards functional goals.

Likewise, protocols are increasingly changing towards early intervention in the Dutch burn centers, in order to prevent deconditioning and improve and accelerate the restoration of functioning. For example, there is attention for early mobilization of burn (even ICU) patients and an increased use of exercise machines (e.g. a bedside-cycle ergometer, rowing machine) and other means like the Kinect to promote and facilitate physical activity during hospitalization.

In the Netherlands, current burn rehabilitation protocols do not comprise (the widely pleaded for) structured in-hospital exercise programs.\textsuperscript{17,18} Yet, if we interpret the results of chapters 2 and 5 as indirect feedback on rehabilitation after burns, this indicates that the current Dutch protocols suffice to restore an important part of physical functioning in children and ado-
lescents with burns, without a structured exercise program. The positive findings in physical functioning might, besides excellent multidisciplinary care, be attributed to the support and stimulation towards a full reintegration and participation in society after burns and the strong resilience that children show after burns. Our findings encourage clinicians and researchers to look beyond the negative physical outcomes of pediatric burns demonstrated in previous studies.

Furthermore, the results in this dissertation indicate that fitness outcomes are not associated with extent of burn in the Dutch population. For example, one of the two subjects that scored significantly low on an aerobic capacity variable had suffered 10% TBSA burns, whereas the other had 41% TBSA. Ganio et al. and Baker et al. have also reported that outcomes were not related to the extent of burn in patients with burns <50%.²⁷,²⁸ Likewise, Ryan et al. (2015) showed that in young adults recovery levels for a.o. ‘social function limited by physical function’ and ‘fine motor function’ tracked toward the non-burned group regardless of the extent of burn.²⁹ Tyack & Ziviani (2003) found that injury factors had no significant impact on functional outcomes after pediatric burns <35%, whereas pre-morbid factors and parent factors had.²⁶ As physical prospects after burns are optimistic nowadays rehabilitation goals should not be limited by reserve, but instead focus on current functioning and optimistic future goals.

Although the current findings on physical functioning were mainly positive, in burn rehabilitation less decline, earlier recovery and better outcomes are always to be strived for. Likewise, the findings that a selection of patients shows long-term deficits in physical functioning should not be overlooked. As soon as this is detected in clinical practice, individual intervention should be initiated. The intervention may be targeted to overcome the patient’s physical and/or psychosocial experienced limitations and barriers to participation or could, for example, comprise an exercise program. Furthermore, it should be kept in mind that individual rehabilitation goals are not addressed in research, even though they are of utmost importance to the patient. For example, imagine a violinist who scores within normal values on all tests, but even so he cannot play the violin because of the scars on his fingers. Each individual values other capabilities for his/her well-being³⁰ and those specific functions are not picked up by general outcome assessments. This emphasizes that personal care, instead of test outcomes, should always remain leading in clinical rehabilitation.

Directions for future research
This dissertation underscored that, as physical functioning is a novel topic in burn research, the current knowledge is just a fragment of what we want and need to know. A part of what we further want to know, is already (being) addressed. Firstly, chapter 5 reported only on a small selection of the data collected in the study described in chapter 4. This provided info on physical capacities without establishing a link to daily life performance. The collected data on physical activity, HRQoL and fatigue will be analyzed soon to put the findings in context, for example to explore a possible association between physical fitness and activities in daily life, as well as to provide their own unique information on a pediatric burn population. Secondly, as a selection of the subjects showed deficits in longer term physical fitness (chapter 5), it is important to indicate potential risk factors for diminished physical fitness in Dutch pediatric burn survivors. A longitudinal study, similar to chapter 4, was recently initiated to this end, as

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well as to gain insight in the evolution of physical fitness after burns, which could guide future interventions.

Another interesting follow-up study, not yet initiated, would include adult burn patients. Our clinical experience is that adults show less resilience than children after burns, which is somewhat supported by literature. Jarrett et al. found that adult burn patients tend to pull away from activities after burns31 and Rowley-Conwy stated that adults have more difficulties coping with burns than children.32 Therefore, a study on physical fitness, physical activity, HRQoL and fatigue in our adult burn population would be interesting.

In the Netherlands our line of research on physical fitness and physical activity is expanding rapidly, and it would be great if this work inspires others around the world to also address this issue. The burn centers in Perth (Australia) and Galveston (Texas, USA) used to be the only other institutes with a similar line of research. It seems promising that, over the past months, the number of related publications from other countries slightly increased.33-36

The primary recommendation for future studies applies to a standard core set of burn outcome assessments, preserving the multidisciplinary approach. This has previously been advocated37,38, but so far outcome assessment in burn care and research has been very inconsistent and different methods were used.17 A standard core set of burn outcome assessments would enable reliable comparison of outcomes between burn- or study populations and thus enlarge knowledge. Hopefully our set of assessments contributes to its development.

Ideally, a certain routine of regular assessments would be implemented as well, so that functioning in patients with burns is repeatedly measured at predetermined time points in both the short and long term using the standard core set of burn outcome assessments. Additionally, international collaboration would expand so that such a routine could be implemented in multiple burn centers worldwide. From the originating consented cohort, a large study population can be selected for each specific research aim, as suggested by Relton et al.39 Possibilities for statistical analyses expand and comparisons of outcomes could easily be made within and between populations based on, for example, treatment characteristics, location of the injury or social support. Although this kind of design is a long way off, it could solve a lot of the challenges encountered in burn research.

When the same outcome measures are used, studies in similar pediatric populations would be valuable to support our findings on physical fitness and to strengthen evidence on physical consequences of pediatric burns (including minor to moderate burns). Of course, similar studies in different pediatric and adult burn populations are valuable as well.

Another recommendation is the use of a mobile exercise lab for follow-up of outpatients. A mobile exercise lab provides a standardized setting, despite its spatial limitations, plus is deemed to improve the feasibility and the inclusion rate in research. A similar setup could work as well for follow-up care and monitoring, especially when aimed at adults, with their many occupations.
However, the abovementioned ideas account to a large extent for highly developed countries like the Netherlands. In less developed countries burn populations are different, clinical needs and treatment possibilities are different and outcomes are probably worse. Yet, to be able to determine needs in a certain population, specific knowledge is necessary and research could contribute to such population-specific knowledge. Hopefully, our work encourages other institutes around the world to more systematically monitor outcomes after burns, desirably not restricted to functional independence, physical fitness or certain populations, and to share their findings. Common knowledge will thereby expand and can subsequently be transferred to and applied in clinical practice.
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References


