CHAPTER 5

Anthropometry, muscular strength and aerobic capacity up to 5 years after moderate to severe pediatric burns: a cross-sectional study

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ABSTRACT

Objective  Physical functioning is of major importance after burn injury in many areas of life, in both the short and the long term. This cross-sectional study aimed to describe anthropometry, muscular strength and aerobic capacity in children and adolescents between 0.5-5 years after moderate to severe burns.

Procedures  Assessments took place in a mobile exercise lab and were completed by 24 subjects (58.3% male; 6-18 years; 10-41% TBSA; 1-5 years post burn). Demographics, burn characteristics and anthropometrics were recorded. Muscular strength in six muscle groups and aerobic capacity were measured using hand-held dynamometry and a graded cardiopulmonary exercise test, respectively. Subjects’ scores were compared with Dutch age- and sex-matched norm values and converted to Z-scores.

Results  On group level, no significant differences between the subjects’ scores and norm values were found. Individually, eight subjects (33.3%), mostly aged 6 or 7, showed significantly low performance on at least one variable: seven for strength, one for aerobic capacity and one for both. No trends were seen indicating an effect of extent of burn or time post burn.

Conclusion  Anthropometry, muscular strength and aerobic capacity are adequate in the majority of Dutch children and adolescents 1-5 years after moderate to severe burns.
MUSCULAR STRENGTH AND AEROBIC CAPACITY AFTER PEDIATRIC BURNS

INTRODUCTION

Burn injuries can have a major impact on physical functioning in both the short and long term. Patients with burns are at risk of getting into the so-called negative spiral of deconditioning, where a condition leads consecutively to inactivity, ongoing deconditioning, deterioration of functioning and, finally, to possible disability. This is highly undesirable considering functioning and participation in daily life, especially in pediatric burn survivors since childhood is a critical life period for development during which also a basis is laid to prevent deficits and disease throughout life. Deconditioning after pediatric burns is a serious concern, as physical fitness was shown to be significantly affected in children with extensive injuries (for review see Disseldorp et al., 2011). Deconditioning after burns is assumed to be induced by (the combination of) prolonged hospitalization and the consequences of the injury itself. Hospitalization (i.e. prolonged bed rest, immobilization, inactivity) after burns can result in a decrease in heart and lung capacity and in peripheral effects like muscle atrophy, osteoporosis and contractures. Furthermore, extensive burns result in a variety of both local and systemic physiological responses. This pathophysiologic response to burn injury is characterized by hypermetabolism, increased catabolism (e.g., of muscle and bone minerals) and insulin resistance and can negatively impact physical fitness.

The current paper is specifically focused on components of physical fitness that the combination of inactivity and pathophysiological consequences of burn injury interfere with. Firstly, several pediatric studies indicated growth delays in both height and weight up to three years after extensive burn injury, due to altered energy expenditure, indicating that anthropometry is affected. Secondly, muscular strength is affected after burns as the increased protein demand leads to catabolism and results in loss of muscle mass. Recent studies additionally suggest impact on mitochondrial function and gene expression in skeletal muscle in a non-burned limb, but full comprehension of these processes is still lacking. Aerobic capacity, lastly, can be affected by a combination of, for example metabolic, muscular and cardiorespiratory effects.

However, the current knowledge on physical outcomes is limited and can therefore hardly be generalized. Firstly, all this information is based on children with extensive burn injuries, whereas the impact of less extensive burns on physical outcomes is hitherto neglected in the literature. The studies on pediatric burns solely included children with burn injuries covering >40% of the total body surface area (%TBSA). Such major pediatric burn injuries are rare in the Netherlands and the US, i.e. represent <5% of cases, and this will probably also apply for other developed countries. Since the current knowledge is based on a selection with respect to extent of burn, it is not representative for the general pediatric burn population. Secondly, the assessments were performed relatively short post burn, considering the severity of the injuries plus long hospitalization. Hence, the results are not necessarily representative for longer term outcomes. Furthermore, the physical outcomes after pediatric burns depend on more factors than burn characteristics only.
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.

METHODS

Subjects
Between August and December 2012, children and adolescents aged 6-18 years were invited to participate if they had been admitted to one of the three Dutch burn centers between 0.5 and five years ago with burn injuries of at least 10% TBSA and/or had a length of stay of more than six weeks. Extensive (pre-existing) comorbidity or (mental) disabilities and insufficient Dutch language proficiency were criteria for exclusion. Informed consent, signed by the participant aged 18 years or by parents / legal representatives and children 12 years and older, was required for participation, as well as a signed pediatric Exercise Pre-participation Screening questionnaire. The Medical Ethical Committee of the University Medical Center Groningen approved this study (NL40183.042.12).

Data collection
As the protocols and instruments for data collection were described in detail previously, a brief description is provided here. Anthropometry, muscular strength and aerobic capacity were assessed in a mobile exercise lab and all data collection has been done by the same researcher.

Subject characteristics
Age, sex, extent of burn, location of burns, presence of inhalation injury, number of surgeries and dates of the burn incident, admission and discharge were obtained from the Dutch Burn Repository for all subjects. These data were also obtained, anonymously, for non-participants to enable a non-response analysis.

Anthropometry
Body height [cm] and weight [kg] were assessed and BMI [kg/m²] was calculated. Waist circumference [cm] was measured between the lowest rib and the hip-bone and skinfold thicknesses [mm] at the triceps, biceps, subscapular and supra-iliacal site.

Muscular strength
Muscular strength [N] was assessed in shoulder abductors, knee flexors and extensors, elbow flexors and extensors and as grip strength. For grip strength assessment, a special full-fist applicator was used on the hand-held dynamometer.

Aerobic capacity
Aerobic capacity was assessed with a graded cardiopulmonary exercise (cycling) test. The instrumented participants started with three minutes sitting in rest, followed by a three minutes
warming-up of unloaded cycling. Thereafter, the work rate (WR [W]) increased with 10, 15 or 20 W·min⁻¹, dependent on body height according to the Godfrey protocol.²⁷,²⁸ Participants were instructed to maintain a pedaling rate of 60-80 revolutions·min⁻¹ and verbal encouragement was given during the test until the patient stopped due to volitional exhaustion. Main outcome variables were \( \text{VO}_{2\text{peak}} \) [ml·min⁻¹], \( \text{VO}_{2\text{peak}} \) per kilogram [ml·kg⁻¹·min⁻¹], WR [W] and WR per kilogram [W·kg⁻¹]. Only tests in which the participant reached maximal level of effort were analyzed; the criteria for maximal effort were a heart rate ≥180 and/or a respiratory exchange ratio (RER) ≥ 1.0 at peak exercise.²⁹

**Data processing**

**Subject characteristics**

For the non-response analysis participating subjects and the non-participants were compared on age, gender, extent of burn, time post burn, the number of surgeries and length of stay, using a Mann-Whitney U test.

**Outcome analyses**

To evaluate whether the subjects displayed affected anthropometry, muscular strength and/or aerobic capacity, their outcomes were compared to the most recently published age- and sex-matched Dutch norm values²³-²⁷,³⁰,³¹ (table 1), which had been obtained using the same protocols and instruments. As for some variables the norm values were not available for all ages, additional data were obtained from original authors²⁶,²⁷ and/or extrapolation or supplement data³² were used based on expert opinion, see Table 1. Using the norm values, results were converted into Z-scores to report individual performance and to equalize influence of all participants on the group mean. Based on the \( \alpha = 0.05 \) level, Z-scores < -1.96 or > 1.96 represent scores significantly deviant from the norm. For strength scores an individual mean Z-score was calculated, based on the individual Z-scores on all strength variables. No subgroup analyses were performed due to the small sample size. Scatter plots with \( R^2 \)-values were used to indicate possible associations between outcomes and burn characteristics. IBM SPSS Statistics 20 was used for general data analyses and Microsoft Excel 2010 for the extrapolations.

**RESULTS**

**Inclusion**

In total 56 children and adolescents were identified in the Dutch Burn Repository whom met the eligibility criteria. Of those, eight were excluded (one deceased; two had (mental) disabilities; two lived abroad; three turned 19 before assessment would take place). Another four could not be contacted. Therefore, 44 children and adolescents were invited to participate. Of these 44, seven sent back the form that he/she would not participate and 12 did not respond to the postings. Signed informed consent(s) were obtained from 25 subjects; the inclusion rate was 56.8%. Results are given for 24 subjects instead of 25 however, as one subject (> 40% TBSA) was anatomically and functionally not able to execute the assessments of the current study, as a consequence of the burn accident. A non-response analyses was performed based on 23 non-participants: the four that could not be contacted, the seven non-participating responders and the 12 non-responders.
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Subject characteristics

Among the 24 subjects (58.3% boys) included in the data analyses, the average extent of burn was 18.1% TBSA (Table 2). Seven subjects displayed burns of more than 20% TBSA. Average time post burn was 3.0 years (Table 2). Length of stay at the burn center varied between five and 78 days, with 77.3% (17 subjects) discharged within four weeks post burn. Three subjects had no surgery at all during initial hospitalization and nobody had suffered inhalation injury. None of the subjects underwent surgery for (at least two) months before assessments.

The distribution of sex (p = .861), age (p = .766), age at the time of the burn injury (p = .949), extent of burn (p = .462), time post burn (p = .101), number of surgeries (p = .475) and length of stay (p = .297) were the same across the group of subjects and the group of non-participants. The high average of extent of burn and the wide range of number of surgeries and of the length of stay in the non-participants group, Table 2, is explained by three exceptionally extensively burned non-participants (55%–65% TBSA).

Anthropometry

No significant deviations from the norm were observed in the group means for all anthropometric variables (Table 3). Generally, the subjects tended to be slightly and non-significantly shorter and ‘rounder’ (height, BMI, waist circumference) than the Dutch norm populations.\(^{21,30,31}\) Three children showed significantly high values on body-fat related variables. Note that analyses on the sum of four skinfold thicknesses were based on 22 subjects instead of 24, due to severe scarring on measurement sites impeding assessment.

Muscular strength

None of the muscular strength variables group means was significantly different from the norm values\(^{25}\) (Table 3). The performances on grip strength measures, which is considered to

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Table 1. Sources of the used norm values and supplement for the measured variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source of norm values</th>
<th>Supplement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropometry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>Schönbeck et al. (2013)(^{30})</td>
<td>NA</td>
</tr>
<tr>
<td>Weight and BMI</td>
<td>Schönbeck et al. (2011)(^{31})</td>
<td>NA</td>
</tr>
<tr>
<td>Waist circumference</td>
<td>Fredriks et al. (2005)(^{32})</td>
<td>NA</td>
</tr>
<tr>
<td>Skinfold thickness</td>
<td>Gerver &amp; De Bruin (1996)(^{24})</td>
<td>NA</td>
</tr>
<tr>
<td>Muscular strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow flexion and extension</td>
<td>Beenakker et al. (2001)(^{33})</td>
<td>17-18 yr: extrapolation</td>
</tr>
<tr>
<td>Knee flexion and extension</td>
<td>Beenakker et al. (2001)(^{33})</td>
<td>17-18 yr: extrapolation</td>
</tr>
<tr>
<td>Shoulder abduction</td>
<td>Beenakker et al. (2001)(^{33})</td>
<td>17-18 yr: extrapolation</td>
</tr>
<tr>
<td>Grip strength *</td>
<td>Wind et al. (2009)(^{36})</td>
<td>6-8 yr: extrapolation</td>
</tr>
<tr>
<td>Aerobic capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All variables *</td>
<td>Bongers et al. (2012)(^{27})</td>
<td>&lt;7.5 yr: Binkhorst et al.</td>
</tr>
</tbody>
</table>

NA, not applied; yr, years of age; *Data was published only in graphs, upon request data were provided by the authors of the source publication to enable Z-score calculation.
represent overall muscular strength, were within normal ranges with one exception: a significantly high score (Z-score = 2.0). The individual mean Z-score for strength, which is based on the individual Z-scores on all strength variables, was significantly low for one subject (7 years old, about 2.5 years post-burn). In the majority of subjects, strength values for shoulder abduction, knee extension and knee flexion were below the norm but not statistically significantly. In total, seven subjects (30.4%) showed significantly low strength in at least one muscle group (there were nine significantly low scores on a total of 136 strength measurements). Five out of these seven subjects were aged 6 or 7. No trend indicating an effect of the extent of burn or time post burn on muscular strength outcomes was observed in the data (Figure 1).

Aerobic capacity
All 24 subjects completed the CPET without complications. Nevertheless, aerobic capacity analyses are based on 22 subjects (Table 3), as data of two 7-year-olds (10% TBSA and 37% TBSA) had to be excluded because criteria for maximal effort (HR ≥ 180 and/or RER ≥ 1.0) were not met. The 22 subjects did not differ from the norm population of Bongers et al. (2012) in terms of height and weight. No significant deviations from the norm were observed in the group means for VO$_{2\text{peak}}$, VO$_{2\text{peak}}$ per kilogram, WR$_{\text{peak}}$ and WR$_{\text{peak}}$ per kilogram (Table 3). For VO$_{2\text{peak}}$ Z-scores ranged from -2.0 to 1.12. Eleven subjects scored higher than the matched norm value and 11 scored equal to or lower than the norm; one subject (10% TBSA) scored significantly below the norm (Table 3 and Figure 2). For VO$_{2\text{peak}}$·kg$^{-1}$ two subjects scored significantly above the norm, whereas one subject (41% TBSA) scored significantly below the norm. No trend indicating an effect of the extent of burn or time post burn on VO$_{2\text{peak}}$ was seen in the data (Figure 2). For work rate all subjects scored within normal ranges (Table 3).
Table 3. Observed values, Z-scores and additional comparisons with the norm values for all measured variables

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Observed values</th>
<th>Z-scores</th>
<th>Comparison with norm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Min</td>
</tr>
<tr>
<td><strong>Anthropometry</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height [cm]</td>
<td>24</td>
<td>146.77</td>
<td>23.49</td>
<td>119.50</td>
</tr>
<tr>
<td>Weight [kg]</td>
<td>24</td>
<td>41.59</td>
<td>18.63</td>
<td>22.10</td>
</tr>
<tr>
<td>BMI [kg/m²]</td>
<td>24</td>
<td>18.27</td>
<td>2.90</td>
<td>14.10</td>
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<tr>
<td>Waist circumference [cm]</td>
<td>24</td>
<td>63.02</td>
<td>8.19</td>
<td>51.00</td>
</tr>
<tr>
<td>Skinfold thickness [mm]</td>
<td>22</td>
<td>27.54</td>
<td>6.58</td>
<td>20.95</td>
</tr>
<tr>
<td><strong>Muscular strength</strong> [Newton]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>23</td>
<td>173.61</td>
<td>90.59</td>
<td>71</td>
</tr>
<tr>
<td>Elbow extension</td>
<td>23</td>
<td>122.91</td>
<td>62.69</td>
<td>44</td>
</tr>
<tr>
<td>Shoulder abduction</td>
<td>22</td>
<td>115.63</td>
<td>58.48</td>
<td>38</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>23</td>
<td>194.09</td>
<td>91.67</td>
<td>76</td>
</tr>
<tr>
<td>Knee extension</td>
<td>23</td>
<td>255.78</td>
<td>111.84</td>
<td>106</td>
</tr>
<tr>
<td>Grip strength</td>
<td>22</td>
<td>93.05</td>
<td>58.61</td>
<td>29</td>
</tr>
<tr>
<td>Individual mean Z-score</td>
<td>23</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Aerobic capacity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO\textsubscript{peak} [L·min\textsuperscript{-1}]</td>
<td>22</td>
<td>1.91</td>
<td>.86</td>
<td>.84</td>
</tr>
<tr>
<td>VO\textsubscript{peak} per kg [mL·kg\textsuperscript{-1}·min\textsuperscript{-1}]</td>
<td>22</td>
<td>44.49</td>
<td>7.60</td>
<td>28.20</td>
</tr>
<tr>
<td>WR\textsubscript{peak} [W]</td>
<td>22</td>
<td>151.41</td>
<td>81.40</td>
<td>55</td>
</tr>
<tr>
<td>WR\textsubscript{peak} per kg [W·kg\textsuperscript{-1}]</td>
<td>22</td>
<td>3.37</td>
<td>.68</td>
<td>2.20</td>
</tr>
</tbody>
</table>

SD, standard deviation; n, number; VO\textsubscript{peak}, oxygen uptake at peak exercise; WR\textsubscript{peak}, peak work rate
Figure 1. Muscular strength outcomes, i.e. the individual mean of Z-scores for all strength variables, including trendline-based associations ($R^2$) to the extent of burn and time post burn.
DISCUSSION

On group level no significant differences in anthropometry, muscular strength and aerobic capacity were found between children and adolescents 1-5 years after moderate and severe burns (10-41% TBSA) and matched Dutch norm values. Furthermore, no trends indicating an effect of extent of burn or time post burn on muscular strength or aerobic capacity were found. On individual level, seven subjects showed a significantly low score on one or more strength variables and two on an aerobic capacity variable.

Regarding the subjects with lower scores on strength, it should be noted that five out of these seven subjects were only six or seven years old. It is likely that for these young children their performance was also influenced by motivation and/or comprehension. Furthermore, regarding the strength data as a whole, we must remark that the norm values fluctuate strongly with age. This might relate to the measurement of choice, as the reliability of hand-held dynamometry is dubious. Nevertheless, hand-held dynamometry is definitely the most feasible measurement available and the most widely used in the clinic.
Comparison with the literature
Other recent studies on physical capacity on pediatric burns all originate from the same research group at Shriners Hospitals for Children (Galveston, Texas) and indicated that subjects with pediatric burns had low lean body mass, knee extensor strength and peak oxygen uptake. Our results, however, should not be compared to these results because of two essential population differences, namely in extent of burn and time of assessments post burn. Firstly, in our population the average extent of burn was 18.1% TBSA, compared to an average of around 55% TBSA in Shriners’ studies. It can be assumed that our subjects deconditioned less, possibly owing to less severe hypermetabolism and catabolism and shorter periods of bed rest and inactivity. Secondly, time of assessment in our study population was 1 to 5 years post burn, compared to ≤1 year post burn in the Shriners’ studies. This longer period post burn offered more time for recovery of disturbed physiological processes as well as time to resume daily activities and/or training to (re)gain, for example, muscular strength.

In the study of Baker et al. (2007), with also a longer period between injury and assessment, results showed that at 14±5 years post burn 35% of the 83 included subjects had deficits in muscular strength in any part of the body. However, again only subjects with very extensive burns were involved (52%±20% TBSA).

Though comparable long-term studies in children after burns are not available, the study from Ganio et al. (2013) on adult burn survivors is interesting for comparison. Ganio and colleagues measured aerobic capacity in 25 adults after burns (17-75% TBSA split-thickness grafts; 1-51 years post burn) and reported that aerobic capacity was disproportionally lower than the age-matched norm values in at least 80% of the adults. Interestingly, the decrements in aerobic capacity were found to be unrelated to the extent of burn or time post burn. The authors emphasized that the mechanisms by which these burn survivors have such low aerobic capacities remain unclear, though they suggested substantial influence of (low) physical activity levels after full recovery of burn injury. We endorse this suggestion.

A possible explanation for the different findings in children and adults might then be that children are both more resilient and more active naturally, which enhances physical outcomes. Pediatric burn survivors appear to cope better than adults and whereas adult burn patients tend to pull away from activities, for children the time to reintegration in school is short. However, these explanations are still speculative as conclusive evidence is lacking. All in all, the current results are novel and provide an interesting addition to the previously published literature.

Study population
We consider our study population convenient for this pediatric burn study and the outcomes representative for the majority of moderate to severe pediatric burn patients in the Netherlands. Firstly, we found the inclusion rate of 56.8% satisfactory, also taking into account what the children and parents had already been through due to the burns. We assume that the use of the mobile exercise lab has contributed to this inclusion rate, as participants did not have to invest time or effort in traveling for the assessments. Furthermore, the mobile exercise lab might have made the study more appealing and it has definitely improved the feasibility
of the study. The use of Z-scores and exhaustive description of the results compensate the statistical limitations of the sample size of 24. Secondly, the study population showed wide ranges in demographics and burn characteristics, as was intended for this study. For time post burn, our subjects showed a nice distribution between the limits of 0.5 to 5 years, supported by the average of 3.0 years post burn. With inclusion up from 10% TBSA, the subjects had moderate to severe burns ranging from 10% to 41% TBSA, of which most were less than 20% TBSA. The non-response analyses underlined that, in terms of demographics and burn characteristics, our study population was a representative sample. However, it must be pointed out that of all eligible children, the four with the most extensive burns did not participate in the assessments of the current study. Furthermore, a possible selection bias could be that children and adolescents who were more interested in sports and an active, healthy lifestyle, or have parents who were thus inclined, were more likely to participate than those who were not. An active lifestyle is reflected in better physical performance and, moreover, in children after burns structured exercise has proven to significantly increase the aerobic capacity.\textsuperscript{3-5, 40} Inclusion of the more physically active children in the population would create a positively distorted perspective about the aerobic exercise capacity after burns.

Future research
The current study has made a start in filling the hiatus in knowledge on physical fitness after pediatric burns and has set a standard for interpretation of future results. We hope to encourage others around the world to address this theme in the near future and that the knowledge that long-term outcomes can be positive, inspires to aim for an early recovery of physical fitness after burns.

The current results on physical fitness are part of a larger multidimensional study which also comprised physical activity measures and questionnaires on health-related quality of life and fatigue, which are currently being analyzed. It will be very interesting to see how subjects’ fitness levels relate to activity levels, health-related quality of life and feelings of fatigue. We are well aware that this paper focuses only on the physical aspects, while psychological and social issues can influence functioning and participation after burns as well. The barriers and motivation to perform physical activity and exercise after pediatric burns are another interesting topic for further research.\textsuperscript{41} Lastly, the evolution of physical fitness and activity after burns in (Dutch) adults deserves attention as well.

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