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Grip and Muscle Strength Dynamometry Are Reliable and Valid in Patients With Unhealed Minor Burn Wounds

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Small burns are common and can cause disproportionate levels of disability. The ability to measure muscle impairment and consequent functional disability is a necessity during rehabilitation of patients. This study aimed to determine the reliability and validity of grip and muscle strength dynamometry in patients with unhealed, minor burn wounds. Grip and muscle strength were assessed three times on each side. Assessment occurred at presentation for the initial injury and again every other day (or every 5 days beyond 10 days post injury) until discharge from the service. Reliability was assessed using intraclass correlation. Minimum detectable differences were calculated for each muscle group. Validity was assessed using regression analysis, incorporating appropriate burn severity measures and patient demographics. Thirty patients with TBSA ≤15% were assessed. Both grip and muscle strength demonstrated very good reliability (intraclass correlation coefficient: 0.85–0.96). Minimum detectable differences ranged from 3.8 to 8.0 kg. Validity of both forms of dynamometry was confirmed through associations with gender for all muscle groups ($P < .001$). In addition, grip strength was associated with the dominant hand ($P = .002$) and time to assessment ($P < .001$). Strength was seen to improve over time in all muscle groups. Grip and muscle strength dynamometry are reliable and valid assessments of strength and are applicable for clinical use in patients who have unhealed, minor burn wounds. (J Burn Care Res 2016;37:388–396)

Burn injuries are associated with a high burden of disease.[1,2] In Western Australia, more than 25,000 patients have been admitted to hospital for burn-related injury since 1983.[3] Similar to other developed nations, in a recent study of Western Australian patients, 90% of the burns population were classified as having a minor burn. At the Western Australia Burns Service, a minor burn is defined as TBSA < 15%,[4] as medical treatment for major burns is started at this level of injury. It has been reported that patients with minor burns can experience considerable disability and absenteeism from work as a result of their injury.[5] Further, hand burn injuries cause disproportionately prolonged alterations in functional and participation outcomes.[6–8]

Treatment and rehabilitation of burns are aimed at returning patients to their preinjury level of function. To support clinicians in assessing the effects of prescribed interventions, reliable and valid outcome measures are necessary.[9] Patients with burn injuries are a unique population who can present challenges to accurate measurement of progress. Therefore, it is important to possess measurement tools that have been tested for use in this specific population. Further, as the majority of burn injuries requiring

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management are classified as minor burns, tools specifically validated for use with a minor burn will have a much broader and accurate application in burn care.

Many clinically applicable outcome measures have previously been validated for measurement of functional recovery in the burns population.[10] These include measures of quality of life: the Burn Specific Health Scale-Brief[11]; the Short Form-36[12]; the quick disability of arm shoulder and hand upper limb functional survey[13]; active range of movement measurements[14]; and balance and coordination tests.[15] More recently, grip strength dynamometry (GSD) was confirmed to be valid beyond 1 month post injury in patients with healed burn wounds.[16] Despite the number of tools available, clinicians still lack a simple and reliable method of measuring clinically significant and real-time changes of muscle strength in patients with unhealed, minor burn wounds.

Isometric muscle strength testing has been reliably applied using handheld muscle strength dynamometry (MSD) in healthy[17] and various clinical[18–20] populations. The handheld dynamometer is a cheap and an effective method for quantifying the isometric muscle strength of an individual. In clinical populations, isometric muscle strength, as assessed by dynamometry, has been shown to correlate with functional performance[21] and exercise capacity,[22] while also being able to detect disease-related impairments in strength.[23] This simple method of muscle strength assessment has potential clinical applicability that has yet to be tested in a burns population.

This study aimed to investigate the reliability, minimal detectable difference, and validity of isometric muscle and grip strength testing in patients with unhealed, minor burn wounds. This study aimed to test the following hypotheses and assumptions of validity (2–6):

1. Intraclass correlation coefficients (ICCs) for GSD and MSD will exceed 0.75, establishing test–retest reliability.
2. Strength as assessed by GSD and MSD will be reduced when TBSA is more extensive.
3. Lower limb MSD values will be reduced in the presence of a lower limb burn.
4. Upper limb MSD and GSD values will be reduced in the presence of an upper limb burn.
5. Muscle strength as assessed by GSD and MSD will improve as pain decreases.
6. Muscle strength as assessed by GSD and MSD will improve over time after burn injury.

METHODS

Participants

Subjects were recruited from Royal Perth Hospital between January and July 2012. Inclusion criteria were as follows:

- more than 16 years of age,
- consent obtained within 96 hours of burn injury, and
- TBSA ≤ 15%.

No limitation was placed on burn agent or depth. Inpatients and outpatients were both considered. The study criteria were designed to enhance generalizability to the broader minor burn population by not placing restriction on location of burn. Participants' exclusion criteria were as follows:

- patients who were medically unstable,
- electrical burn injuries,
- musculoskeletal injury or disease, which would contraindicate muscle strength testing,
- neurological conditions less than 3 months old, and
- patients who were unable to comprehend instructions.

Procedure

All subjects provided consent to participate, and ethics approval was granted by the Clinical Quality and Safety Register BCORP CSQU 080429-1. As this project was particularly concerned with minor burn wounds, both admitted and ambulatory patients were recruited. Testing of patients began on their initial presentation to the burns service. After a standardized warm-up of active shoulder, elbow, and lower limb range of motion exercises (see Appendix 1, Supplemental Digital Content 1, at http://links.lww.com/BCR/A58), patients underwent testing of muscle groups: biceps, triceps, deltoids, hamstring, and quadriceps using a muscle strength dynamometer. Grip strength was measured with GSD. These muscle groups were chosen for assessment as they were considered key to completing many daily functional activities and were amenable to being repeatedly assessed in a standardized manner.

Testing was completed every second day until 10 days post injury or until discharge. Where burns care extended beyond 10 days, assessment continued every fifth day until discharge from the acute burn service. Left and right sides were assessed three times on each day of testing. After each testing session, using a visual analog scale, pain score was recorded for the level of pain experienced during the testing

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process. Testing was ceased for 48 hours after surgical intervention.

Outcome Measurement

Grip Strength Dynamometry. Hand grip strength was assessed with the Jamar handheld dynamometer (Surgical Synergies, SI Instruments, Hilton, Australia). The Jamar dynamometer measures peak grip strength on a scale from 0 to 90 kg of force and has been regarded as the benchmark for grip strength assessment.[24] Assessment was undertaken in 90° of elbow flexion. Each participant performed three tests, alternating left and right hands. The standardized testing positions and instructions were applied for each participant (see Appendix 1, Supplemental Digital Content 1, at http://links.lww.com/BCR/A58; Figure 1).

Muscle Strength Dynamometry. Peak isometric muscle strength was assessed using the Lafayette Muscle Meter no 01163 (SI Instruments, Australia). This is a handheld dynamometer that records muscle strength in kilograms, pounds, or Newtons of force. In this study, kilograms was utilized. The Lafayette muscle meter was chosen for ease of application in an acute burns population. The low cost compared to other strength assessment equipment potentially makes it a widely available tool for clinicians. Three make-tests were performed on each muscle. The testing was performed by one assessor. Standardized positions and instructions were utilized for each participant in accordance with the American Society of Hand Therapists as outlined in Mathiowetz et al[25] (see Appendix 2, Supplemental Digital Content 1, at http://links.lww.com/BCR/A59, Figure 2A–E).

Figure 1. Grip strength dynamometry testing position.

Data Analysis

Analysis was performed using Stata V.12 (Stata Corp, Chicago, IL). Significance was set at $\alpha = 0.05$. The distribution of each muscle strength variable was checked to determine the most appropriate analytical methods.

Descriptive Analysis. Patient characteristics were summarized using medians, ranges, and proportions as appropriate.

Reliability. ICCs were calculated using variance components from hierarchical linear mixed models (HLMMs) with no covariates. This was undertaken between all three tests of the dominant side for each muscle group during a single testing session for the same person. For this reliability study, data from the first testing session were chosen. This ensured that analysis of data from the acute phase of wound healing was undertaken, to truly understand the performance of the tools in patients with wounds and pain. ICCs were calculated again excluding the first test in the case, where a learning effect was identified. Fatigue or learning effects were investigated by examining the differences in the estimated group-wise mean strength between tests using an HLMM.

These analyses were repeated adjusting for the potential effect of pain during assessment on the reliability of the muscle strength testing. An ICC > 0.75 was accepted as having adequate reliability, and an ICC > 0.90 was defined as excellent reliability.[26]

Minimum Detectable Difference. Minimum detectable difference (MDD) was calculated for each muscle group, based on the second and third tests from the first day assessments, using the following formula:

$$\begin{aligned}\text{MDD}\ (95\%) &= t \times \text{SD}_{\text{baseline}} \\ &\quad \times \sqrt{(2(1 - \text{rho\_testretest}))}\end{aligned}$$

where the t-distribution value corresponding to the sample size was substituted for *t*, and the SD of the second test sample was used for $\text{SD}_{\text{baseline}}$. This value allows an understanding of the real change measureable by the tool.[15]

Validity. HLMMs regression analyses were also used to evaluate associations between clinical variables and strength measurements from the first day of assessment of each muscle group. Clinical variables used to examine validity included time to assessment post burn, gender, age, side dominance, TBSA, pain,

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Figure 2. Muscle strength dynamometry testing positions: A. biceps, B. triceps, C. deltoids, D. hamstrings, E. quadriceps.

requirement for surgery, and location of burn. Surgery was included as a quasi-measure of burn depth and therefore severity. Univariate analysis was performed, followed by multivariable analyses. Due to the expected large influence of gender, all clinical measures were initially included in the multivariable analyses to ensure that potential effects emerging after adjusting for gender were not missed. Nonsignificant variables were then removed in a manual backward stepwise process until the final model was determined. The level of significance accepted was $\alpha < 0.05$.

Temporal Recovery. Longitudinal analysis using HLMM was performed on sentinel measures of strength for upper and lower limbs, using all three assessment measures for each person. Sentinel measures of biceps and quadriceps strength were selected to be the key limb muscle groups, in addition to grip strength. The influence of gender, age, dominance, TBSA, pain, and surgery on muscle strength was analyzed for each muscle group, with time post burn accounted for in all cases. Interactions between time and clinical measures were investigated for variables that may have affected the pattern of muscle strength change over time. Variables that displayed a significant association with muscle strength and time were included in multivariable analyses, and nonsignificant associations were subsequently removed in a stepwise manner to determine the final model.

Assumptions of linearity were assessed using plots with locally weighted scatterplot smoothing, multivariable regression splines, and fractional

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Table 1. Descriptive statistics n = 30

	n (%) or Median (IQR)*
Male gender	25 (83.3)
Age	28.5 (20)*
TBSA	5.0 (2.8)*
Surgery	13 (43)
Right hand dominant	27 (90)
Upper limb burn	17 (56.7)
Hand burn	14 (46.7)
Lower limb burn	10 (33.3)
Foot burn	5 (16.7)

IQR, interquartile range.
*Data presented as median (IQR).

polynomials. When nonlinearity was identified, piecewise regression was performed based on knots determined by the regression spline calculations to facilitate a simpler interpretation of regression coefficients.

All HLMMs employed maximum likelihood estimation that ensures patients with some missing observations on the outcome are not excluded, thereby reducing the introduction of bias. Maximum likelihood estimation maximizes together the likelihood based on complete data and the likelihood based on partial data to produce more robust parameter estimates as long as missing data are missing at random.

RESULTS

Descriptive

A sample of 30 patients was recruited for this study. Descriptive statistics are detailed in Table 1.

Reliability. Quadriceps and hamstrings assessments demonstrated a significant learning effect between tests 1 and 2, which was not evident between tests 2 and 3. Grip strength measures demonstrated a fatigue effect between tests 1 and 2, again not evident between tests 2 and 3. Intraclass correlations based on tests 2 and 3 exceeded 0.9 for all muscle groups other than quadriceps (ICC = 0.85; Table 2). Pain did not influence the ICC scores.

Minimum Detectable Difference. The MDDs for muscle strength assessments ranged from 3.8 to 8.0 kg for all muscle groups and grip strength (Table 2). Grip exhibited the greatest MDD (8.0 kg) and deltoids the lowest (3.8 kg) for muscle strength testing.

Validity. Males demonstrated significantly stronger muscle strength in all univariate models. Time post burn was associated with increased hamstring (P = .007) and grip strength (P = .007), while dominance was associated only with grip strength (P = .002). Burn injury factors such as surgery, pain, and TBSA were not associated with muscle and grip strength results (Table 3). However, multivariate analysis did demonstrate changes in the associations of these variables.

In multivariate models, male gender continued to be associated with increased muscle strength in all groups. Grip strength was positively associated with dominance (P < .001) and time since burn (P < .001). However, increasing age and right-sided hand burns were associated with decreased grip strength (P < .001). Hamstring strength was positively associated with time post burn injury and pain scores (P < .001), yet negatively associated with TBSA (P < .001). Quadriceps strength decreased with advancing age (P = .003; Table 4).

Temporal Recovery. Gender and dominance were associated with muscle strength for each of the sentinel muscle groups (biceps, quadriceps, and grip). Male gender and the dominant side were associated with greater muscle strength for biceps, quadriceps, and grip strength (Table 5).

Biceps and quadriceps strength increased in a linear trajectory. Small changes in strength were seen each day post burn, biceps increased 0.1 kg per day (95% confidence interval [CI]: 0.02, 0.18,

Table 2. Intraclass correlation coefficients and MDD (kg) for all muscle groups

		Tests 1, 2, and 3	Tests 2 and 3	
	N	ICC (95% CI)	ICC (95% CI)	MDD*
Biceps	29	0.91 (0.86, 0.95)	0.94 (0.90, 0.96)	5.55
Triceps	29	0.85 (0.76, 0.91)	0.91 (0.85, 0.94)	4.19
Deltoid	29	0.89 (0.83, 0.93)	0.92 (0.88, 0.95)	3.87
Hamstring	28	0.89 (0.82, 0.93)	0.90 (0.84, 0.94)	5.88
Quadriceps	28	0.80 (0.70, 0.87)	0.85 (0.76, 0.91)	7.83
Grip	30	0.95 (0.92, 0.97)	0.96 (0.93, 0.98)	8.02

CI, confidence interval; *ICC*, intraclass correlation coefficient; *MDD*, minimum detectable difference.
*Based on tests 2 and 3.

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Table 3. Univariate hierarchical linear mixed models of first assessment for muscle groups

	Biceps	Triceps	Deltoids	Hamstring	Quadriceps	Grip
Time since burn						
Coefficient (95% CI)	1.37 (−0.31, 3.05)	0.78 (−0.57, 2.13)	0.77 (−0.43, 1.96)	**2.36 (0.67, 4.07)**	1.27 (−0.64, 3.19)	**4.62 (1.28, 7.95)**
P	.11	.26	.21	**.007**	.19	**.007**
Gender male						
Coefficient (95% CI)	**12.1 (7.89, 16.3)**	**9.54 (6.35, 12.7)**	**9.06 (6.33, 11.8)**	**11.1 (6.89, 15.4)**	**10.4 (4.93, 15.8)**	**26.6 (18.1, 35.1)**
P	**.001**	**.001**	**.001**	**.001**	**.001**	**.001**
Age						
Coefficient (95% CI)	0.02 (−0.11, 0.14)	0.06 (−0.04, 0.15)	0.67 (−0.02, 0.15)	−0.01 (−0.14, 0.11)	−0.09 (−0.22, 0.04)	−0.18 (−0.44, 0.07)
P	.78	.25	.11	.83	.18	.15
Dominant side						
Coefficient (95% CI)	0.87 (−0.85, 2.59)	0.03 (−0.89, 0.95)	−0.02 (−0.87, 0.83)	0.69 (−0.36, 1.74)	0.64 (−1.0, 2.27)	**4.98 (1.75, 8.20)**
P	.32	.94	.96	.19	.45	**.002**
TBSA						
Coefficient (95% CI)	0.43 (−0.44, 1.30)	0.17 (−0.52, 0.85)	0.11 (−0.50, 0.72)	−0.07 (−0.92, 0.78)	−0.07 (−1.04, 0.88)	0.16 (−1.70, 2.01)
P	.33	.64	.71	.87	.87	.87
Pain						
Coefficient (95% CI)	0.42 (−0.81, 1.65)	−0.09 (−1.06, 0.89)	0.25 (−0.62, 1.11)	1.04 (−0.13, 2.21)	1.12 (−0.19, 2.43)	1.12 (−1.48, 3.73)
P	.51	.86	.57	.08	.09	.39
Surgery						
Coefficient (95% CI)	1.17 (−3.33, 5.66)	−0.85 (−4.44, 2.75)	−0.92 (−4.06, 2.22)	0.69 (−3.89, 5.27)	2.72 (−2.42, 7.85)	1.34 (−8.24, 10.9)
P	.61	.64	.57	.77	.30	.78
Burn location*						
Left						
Coefficient (95% CI)	−3.69 (−9.87, 2.48)	−1.23 (−6.17, 3.72)	−0.76 (−5.01, 3.48)	0.65 (−6.65, 7.96)	−2.28 (−10.5, 5.93)	−7.13 (−20.5, 6.20)
P	.24	.63	.72	.86	.59	.29
Right						
Coefficient (95% CI)	−0.22 (−7.80, 7.36)	−1.30 (−7.32, 4.72)	3.92 (−1.27, 9.11)	−3.49 (−12.3, 5.34)	−1.39 (−11.4, 8.65)	2.11 (−14.1, 18.3)
P	.95	.67	.13	.43	.79	.79
Bilateral						
Coefficient (95% CI)	1.97 (−3.12, 7.06)	1.55 (−2.64, 5.75)	2.36 (−1.12, 5.84)	1.57 (−5.01, 8.15)	−0.36 (−9.02, 8.30)	1.33 (−9.65, 12.3)
P	.44	.46	.18	.64	.93	.81

CI, confidence interval.

Significant results in bold ($P < .05$).

*Arm burn for upper limb muscle groups, leg burn for lower limb muscle groups.

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Table 4. Final multivariate hierarchical linear mixed models of first assessment

Muscle Group	Variable	Coefficient (95% CI)	*P*
Biceps	Gender male	12.8 (8.70, 16.8)	**<.001**
	Constant	14.2 (10.1, 18.3)	**<.001**
Triceps	Gender male	10.4 (9.58, 11.2)	**<.001**
	Constant	11.8 (8.73, 14.8)	**<.001**
Deltoids	Gender male	8.77 (5.99, 11.5)	**<.001**
	Constant	11.9 (9.02, 14.4)	**<.001**
Hamstrings	Days post burn	1.24 (0.91, 1.57)	**.03**
	Gender male	11.4 (10.3, 12.4)	**<.001**
	TBSA	−0.50 (−0.63, −0.38)	**.044**
	Pain	0.88 (0.69, 1.06)	**.015**
	Constant	14.6 (13.3, 15.9)	**<.001**
Quadriceps	Gender male	12.2 (7.33, 17.1)	**<.001**
	Age	−0.15 (−0.25, −0.05)	**.003**
	Constant	32.9 (27.9, 38.0)	**<.001**
Grip	Days post burn	2.27 (2.11, 3.34)	**<.001**
	Gender male	27.9 (25.9, 29.8)	**<.001**
	Age	−0.31 (−0.36, −0.26)	**<.001**
	Dominant	4.98 (3.72, 6.24)	**.002**
	Burn location*	−1.85 (−7.54, 3.84)	.52
	Burn location†	−7.23 (−8.89, −5.57)	**.002**
	Burn location‡	−2.49 (−6.35, 1.38)	.21
	Constant	27.4 (20.8, 33.9)	**<.001**

CI, confidence interval.
Significant results in bold ($P < .05$).
*Left-side hand burn only. Reference group no burn on hand.
†Right-side hand burn only.
‡Bilateral hand burn.

P = .012) and quadriceps 0.18 kg per day (95% CI: 0.04, 0.33, P = .011). Grip followed a nonlinear pattern (Table 5). Between days 1 and 3, grip strength was found to decrease by 1.76 kg per day (95% CI: –2.9, –0.62, P = .002), while between days 4 and 6 grip strength was found to increase by 1.13 kg per day (95% CI: 0.41, 1.85, P = .002). No significant changes in grip strength were detected for the period following day 6 (P = .29).

DISCUSSION

This project confirmed handheld MSD and GSD to be reliable assessments of strength in patients with unhealed minor burn wounds. All muscle groups had excellent reliability, except for quadriceps, where the ICC was lower (ICC = 0.85), though reliability remains acceptable for clinical use. Due to the learning and fatigue effects noted between tests 1 and 2, in the clinical setting, a practice test is advised before formal testing.

The MDD for GSD in this study was greater than in our previous work with burns patients who were tested at least 1 month after their injury.[16] We deduce that the decrease in sensitivity of grip strength reflects the variability of hand grip performance due to the presence of an unhealed wound and the associated inflammatory response, which may affect muscle activation and strength. For MSD, this study is the first instance, to our knowledge, of reporting the MDD in a burns population. Clinician application of these values makes for a more constructive tool in measuring the effect of chosen interventions. The MDD is important in the interpretation of clinical testing as it will indicate the change in muscle strength measured before clinicians can assume a real change has occurred.

Muscle strength was significantly greater for males in all muscle groups. Our finding aligns with what has been demonstrated in the general population.[27–29] Muscle strength is known to decrease with age,[27,29] similarly, in our group of acute burns patients, age was significantly associated with decreasing grip and quadriceps strength. Grip strength was significantly greater in the dominant hand, again mirroring the general population.[29] Based on these findings, validity can be confirmed for these measurement tools.

The temporal recovery of muscle strength has assisted to confirm validity of dynamometry in patients with unhealed, minor burn wounds. Sentinel

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Table 5. Multivariable regression models assessing muscle strength over time

Muscle Group	Variable	Coefficient (95% CI)	*P*
Biceps	Days post burn	0.10 (0.02, 0.18)	**.012**
	Gender male	12.3 (8.28, 16.2)	**<.001**
	Dominant	0.49 (0.06, 0.91)	**.024**
Quadriceps	Days post burn	0.18 (0.04, 0.33)	**.011**
	Gender male	10.3 (5.41, 15.2)	**<.001**
	Dominant	1.12 (0.40, 1.84)	**.002**
Grip	Days 1–3	−1.76 (−2.90, −0.62)	**.002**
	Days 4–6	1.13 (0.41, 1.85)	**.002**
	Days 7–20	0.11 (−0.09, 0.31)	.286
	Gender male	26.1 (17.1, 35.0)	**<.001**
	Dominant	3.70 (2.89, 4.51)	**<.001**

CI, confidence interval.
Significant results in bold ($P < .05$).

assessments of upper and lower limb strength showed improvement during the first 20 days of recovery post burn. Grip strength initially decreased during the first 3 days post burn and then improved during the next 3 days, whereas biceps and quadriceps demonstrated recovery in a linear manner. This confirms our hypothesis of a measureable change in muscle strength over time. As might be expected, dominance and gender were associated with the magnitude of muscle strength, while the pattern of recovery was not affected by these variables.

However, not all results were as predicted. The location of the burn wound in our study did not influence muscle strength measurements. However, the presence of a right-sided hand burn was associated with reduced grip strength when compared to no hand burn. This effect was not evident for a left-sided hand burn. We surmise this is most likely to be due to artifact secondary to the small subgroup size for hand burns in this study (Table 1). Additionally, our assumption of associations of muscle strength with burn severity and pain was not confirmed in this study. The hamstrings were the only muscle group to demonstrate a statistical association; however, the magnitude of this was below the MDD and thus, we would suggest did not reach clinical significance. No other associations with surgery, TBSA, or pain were demonstrated. While sensitive, we acknowledge that this methodology may not be sensitive enough to detect all differences due to variables that could be considered influential to strength changes in patients with minor burn wounds.

In a minor burn sample such as this, the effect of burn injury factors on muscle strength may not be as pronounced as in more severe burns. Further, the model of care provided for burns patients in this setting is one of the rehabilitations starting from the time of injury. Undertaking early rehabilitation, not limited to therapeutic exercise, may assist to hasten the return of strength and functional ability after a burn injury. In practice, we have a strong focus on providing adequate pain relief to facilitate engagement in rehabilitation and normal function throughout the entire day. Additionally, we observe that skeletal muscle contractions performed during muscle testing and exercise have a positive influence on perceived pain, helping to optimize function, movement, and muscle strength after burn injury. From our presented results, we would hypothesize that in burn patients with unhealed, minor wounds, the severity and location of the injury should not confound the use of muscle and GSD, which are useful tools for measuring patient progress and outcome.

CONCLUSION

Muscle and GSD are reliable and valid clinical tools that are appropriate to use in assessment of the change of muscle strength in patients with unhealed, minor burn wounds.

LIMITATIONS

Although reliability and validity are demonstrated, we appreciate that the limited sample size of this study may contribute to the inconsistent associations of muscle strength assessment with burn injury factors. Additionally, our data had limited precision in the categorization of depth of injury, therefore, surgery was utilized as a quasi-measure of burn depth and thus injury severity.

It has been considered that difficulty in stabilizing the dynamometer by hand during muscle testing may have contributed to the reduced ICC for

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the quadriceps muscle group. This has previously been documented as a factor in testing on other populations.[30]

FUTURE STUDIES

While these results are applicable to the majority of burn patients, additional investigation into larger burn injuries would improve generalizability of our results. Testing the reliability of the MSD to assess multijoint movements and the effect of an external stabilizer in burns patients on MSD reliability would also be beneficial. Another area for future work could investigate an association of early strength dynamometry measurements with functional and quality of life outcomes in the burns patient.

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