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Research Article

Changes in grip strength, depression, and cognitive functioning during medical stabilization for anorexia nervosa: Exploring the utility of grip strength as a marker of severity

Kamila Cass, PhD[1,2,*], Dan V. Blalock, PhD[3,4], Jamie Manwaring, PhD[1,2,5], Delaney Wesselink, PT, DPT[1], Cheryl Lundberg, PsyD[1], Philip S Mehler, MD[1,2,5]

[1]ACUTE Center for Eating Disorders and Severe Malnutrition at Denver Health, 723 Delaware St, Denver, CO, 80204, USA

[2]Department of Medicine, University of Colorado School of Medicine, 13001 E 17th PL, Aurora, CO, 80045, USA

[3]Center of Innovation to Accelerate Discovery and Practice Transformation, Durham Veterans Affairs Medical Center, Durham, North Carolina, USA

[4]Department of Psychiatry and Behavioral Sciences, Duke University School of Medicine, Durham, North Carolina, USA

[5]Eating Recovery Center, 7351 E Lowry Blvd, Denver, CO, 80230, USA

*Author for correspondence:
Email: kamila.cass@dhha.org

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Abstract

Objective: It is not uncommon for individuals with anorexia nervosa (AN) to attempt to appear healthier than the reality, underscoring the value of establishing objective markers of AN severity to guide effective treatment. Grip strength has been proposed as one such objective marker, and the purpose of this prospective study was to explore associations in grip strength, depression, and cognitive functioning in extreme AN, including those at the lowest body weight, as these factors are associated in other populations.

Method: Forty-nine patients with extreme AN completed a standard grip strength assessment, the Beck Depression Inventory-2 (BDI-2), the Massachusetts General Hospital Cognitive and Physical Functioning Questionnaire (CPFQ), and the Coding subtest of the Wechsler Adult Intelligence Test, 4th edition, at admission and discharge from an inpatient medical stabilization unit for eating disorders. Paired-samples t-tests were used to examine admission-discharge change. Pearson correlations were used to examine associations among assessments.

Results: At admission, only 4-10% of patients exhibited normal grip strength, depending on the hand tested. Patients scored in the severely depressed range on the BDI-2 and reported markedly diminished cognitive functioning. For most patients, measures improved from admission to discharge. Among the most low-weighted patients (body mass index (BMI) ≤ 12.41 vs. higher), grip strength and depression were correlated with each other and were extraordinarily severe.

Discussion: Results indicate that positive physical, psychological, and cognitive changes can be possible within weeks of hospitalization for severe AN. Among the most low-weighted patients, depression and grip strength may function as "bedfellows."

Conclusion: Utilization of grip strength assessments may offer a quick, objective marker of severity of AN and may lend credence to providers' treatment recommendations.

Keywords: Anorexia nervosa, Grip strength, Depression, Cognitive functioning, Malnutrition, Medical stabilization

List of Abbreviations: AN: Anorexia Nervosa; AN-BP: Anorexia Nervosa Binge-Eating/ Purging Subtype; AN-R: Anorexia Nervosa- Restricting Subtype; BMI: Body Mass Index; DSM-5-TR: Diagnostic and Statistical Manual of Mental Disorders, 5th Edition, Revised; BDI-2: Beck Depression Inventory-2; CPFQ: Massachusetts General Hospital Cognitive and Physical Functioning Questionnaire; IBW: Ideal Body Weight; U/L: Units/Liter; WAIS-IV: Wechsler Adult Intelligence Test, 4th Edition

Introduction

Anorexia nervosa (AN) is a serious psychiatric illness that carries at least a four-fold increased risk of death versus aged-matched controls [1]. However, women with AN and concurrent depression are eight times more likely to die compared to the general population and 24 times more likely to die from unnatural causes [1]. In the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition [2], those in the extreme category, with a body mass index (BMI) of less than 15 kg/m^2, are arguably at the greatest medical risk. Yet given the ego-syntonic nature of the illness, it is not uncommon for individuals with AN to decline a higher level of care, to report little functional impairment or psychological distress [3], or to attempt to falsely elevate weight through water loading or other means [4]. This underscores the value of establishing objective markers for the severity of AN to help objectify their illness, guide effective treatment, and attenuate the risk of premature death.

Grip strength has been proposed as one such objective marker in assessing the severity of AN [5], yet few studies have explored this avenue. Physiologically, grip strength is an effective biomarker of strength and functional ability in other populations such as middle aged and older adults, and patients with cancer or vascular disease, and has been shown to predict fracture risk, likelihood of hospitalization, and all-cause mortality [6-15]. Grip strength has also been explored as a potential biomarker of malnutrition [7,16]. Malnutrition causes metabolic changes in skeletal muscles and muscular function and morphology [17,18], leading to overall decreased skeletal muscle mass [16,19]. Grip strength is related to body mass index (BMI; kg/m^2) with findings of lower BMI associated with lower grip strength [20]. Concerningly, low BMI and low muscle strength are associated with an increased risk of death [21].

Given that low BMI and malnutrition are hallmarks of AN, it is surprising that, to our knowledge, only two studies have explored grip strength in AN. One study that measured hand grip strength in 10 individuals with AN, with an average BMI of 13.6 kg/m^2, found that grip strength was not only diminished, but it was also a good predictor of BMI, allowing for an objective and accurate appraisal of patients' health status in lieu of patients' typical attempts to mask low weight [22]. A second retrospective study of grip strength, in 475 patients with extreme to severe AN undergoing medical stabilization, found extreme deficits in grip strength at the time of admission, with only 2% of the cohort having normal levels of grip strength [5]. Individuals with the lowest grip strength measurements also had the lowest BMI and were found to have an increased fall risk. As such, including an objective grip strength measurement in the assessment of the appropriate level of care for patients with AN could be valuable and aid in identifying patients at a lower body weight and more precarious state of health, for whom a higher level of care would be needed to keep them safe.

Exploration of grip strength in AN may also be useful given the relationship between grip strength and other psychiatric and neuropsychological factors impacted by AN, namely depression and cognitive functioning. Approximately 40% of those with AN experience concurrent depression, which increases all-cause mortality, including risk for suicide, and predicts a poorer outcome [1,23]. Numerous studies have shown a relationship between grip strength and increased depression in other populations, with lower hand-grip strength associated with higher odds of having depression [24,25]. In one study of middle aged and older adults, being in the highest quartile of grip strength decreased the odds of depression by 47% [26]. The relationship between grip strength and depression in AN has only been studied once, retrospectively, finding no association [5]. However, no standardized assessment of depression was utilized in that study, and thus further exploration is warranted.

Cognitive functioning is another area that is impacted by AN, as malnourishment from AN leads to an average brain volume reduction of 3.7% in grey matter and 2.2% in white matter among adults acutely ill with AN [27]. Indeed, the severity of starvation is implicated in the amount of brain volume loss, with patients with AN at a lower BMI (<15) showing the most volume loss [28]. The functional consequences resulting from grey and white matter loss manifests in neuropsychological performance, including reduced reasoning and perceptual organizational skills [29] along with impaired information processing speed and planning abilities [30].

Therefore, the purpose of this study is to prospectively explore grip strength, depression, and cognitive functioning in patients with extreme AN, hypothesizing that positive improvements in each of these domains would be found over the course of medical stabilization, underscoring the possible benefit of utilizing grip strength as an objective marker of severity of AN. We also sought to explore associations among these variables with respect to BMI, hypothesizing that those at the most extreme levels of malnourishment may be particularly depressed or cognitively compromised.

Materials & Methods

Participants

A total of 49 patients were recruited from an inpatient medical stabilization unit for extreme eating and feeding disorders located in Denver, Colorado. Typical criteria for admission to the unit include one or more of the following: weight less than 70% of the patient's Ideal Body Weight (IBW) or a BMI less than 15 kg/m^2, a history of serious medical complications as a result of the eating disorder (electrolyte imbalance, edema, organ failure, cardiac irregularities or gastrointestinal complications), a need to detoxify from, or avoid complications from, a purging behavior (vomiting, laxative or diuretic abuse), or a history of previously experienced bouts of refeeding syndrome. Eligible patients were adults who were diagnosed with either anorexia nervosa-restricting subtype (AN-R) or binge-eating/ purging subtype (AN-BP) with an IBW less than 70% on admission or BMI < 15 kg/m^2.

Eligible patients were recruited and enrolled within the first 72 hours of admission. Patients were assessed at two time points: within 72 hours of admission and within 72 hours of discharge. Patients were excluded from the study if their stay was less than 7 days or if they became involuntary patients at any time during their stay. Informed consent was obtained by research assistants before completion of admission assessments. The study was approved by the Colorado Multiple Institutional Review Board.

Procedure

Grip strength was assessed by a licensed physical therapist on the medical stabilization unit. Licensed psychologists or research assistants presented the questionnaires to patients and psychologists administered a cognitive performance test to patients. Because grip strength can be impacted by myositis [31], potentially affecting findings related to muscle strength, serum aldolase levels were drawn with morning standard of care labs on patients' first or second day of admission. If the participant's aldolase level was >8.1 (above the normal range of 1.5-8.1 U/L), a second lab draw was conducted within 3 days of discharge. Data from patients with elevated levels of aldolase at discharge (N = 1) were not included in the study.

Measures

Grip strength: Grip strength in kilograms was assessed using a Grip Strength Dynamometer, an evaluation tool that measures isometric grip force using the Jamar hand dynamometer, the gold standard device for measuring grip strength [32-34]. Patients were asked by the physical therapist to use one hand to squeeze the dynamometer as hard as possible and then repeat using the other hand, for a total of 3 readings per hand. The average value achieved using each hand was recorded. Grip strength was assessed at both admission and discharge (See **Appendix A)** for Jamar grip strength norms for females and males.

Depression: Depression was assessed using the Beck Depression Inventory-2 (BDI-2), a 21-item self-report measure assessing symptoms of depression over the past 2 weeks [35]. Items are scored on a 0-3 scale. The total score of the BDI-2 ranges from 0 to 63, with classification of low (1-16), moderate (17-30), and severe depression (31-63). The measure has high reliability and capacity to discriminate between depressed and non-depressed individuals [36]. Internal consistency in the current sample was excellent at admission (α = .87) and discharge (α = .89).

Cognitive functioning: Cognitive functioning was assessed in two ways, via self-report and a cognitive performance test. Self-reported cognitive functioning was assessed using the Massachusetts General Hospital Cognitive and Physical Functioning Questionnaire (CPFQ), a patient-report measure consisting of 7 questions (rated on a 1 to 6 scale) related to (1) motivation, (2) alertness, (3) energy, (4) focus, (5) recall, (6) ability to find words, and (7) sharpness/ mental acuity. Items are rated on a 1 to 6 scale: (1) greater than normal functioning, (2) normal functioning, (3) minimally diminished functioning, (4) moderately diminished functioning, (5) markedly diminished functioning, and (6) totally absent functioning, with higher scores indicating more self-reported deficits in cognitive and executive functioning [37]. The CPFQ is reliable and valid and is sensitive to change within treatment [37,38]. Test-retest reliability is strong [37]. Internal consistency in the current sample was excellent at admission (α = .90) and discharge (α = .80).

The Coding subtest of the Wechsler Adult Intelligence Test, 4th edition (WAIS-IV), was used to measure cognitive performance. The Coding test is a visual paper and pencil test that requires individuals to match numbers with symbols based on a "key" at the top of the page by drawing the correct symbol in the boxes provided. The task yields a raw score (the number of items that are answered correctly) and a scaled score. Scaled scores have a mean of 10 and a standard deviation of 3, with scores between 8 and 12 considered to be in the average range, with a corresponding percentile rank of 25-75. Scaled scores from 1-7 are below average, with a corresponding percentile rank of 1-16. Scaled scores of 13-19 are above average, with a corresponding percentile rank of 84-99 [39]. Scaled score changes of one-third of a standard deviation or more have been used to signify meaningful change [39,40]. The task involves attention, processing speed, and executive functioning and is regarded as a brief and simple stand-alone test to detect meaningful change in cognitive functioning, including in individuals with depression [40-43]. The Coding test also correlates with real-world functional outcomes, such as the ability to complete activities of daily living [42]. Though the field lacks consensus regarding which neuropsychological test or tests are most appropriate for use with AN patients [44], the Coding test has been proposed as a stand-alone measure due to its high sensitivity to change within a patient, including impairments and improvements in working memory, processing speed, and executive functioning [42]. Test-retest reliability is also strong (α = .86) [39].

Statistical analysis

Pearson correlations were used to examine associations between two continuous variables. Paired-samples t-tests were used to examine change in variables from admission to discharge. All analyses were performed in R (versions 4.3.1; R Core Team) [45].

Results

Descriptive statistics are presented in **Table 1**. The vast majority of patients self-identified as female (93.9%; N = 46), with 6.1% male (N = 3), with an average age of 32.7 (range = 18 to 61). All patients met criteria for a current diagnosis of either AN-R (61.2%. N = 30) or AN-BP (38.8%, N = 19). BMI at admission ranged from 8.84 to 16.08 kg/m^2 (M = 12.3 ± 1.27) and 13.4 to 17.4 (M = 15.2 ± 0.85) at discharge. Average length of hospitalization was 30.6 days (± 12.1). Mean age of onset of AN was 17.0 years (± 5.34) with an average duration of illness of 14.8 (± 12.7) years. Patients had a mean of 1.98 (± 1.42) co-occurring psychiatric diagnoses.

Table 1. Participant demographics.

	(N=49)
Female (N, %)	46 (93.9%)
Age (M, SD)	32.7 (13.3)
Admit BMI (M, SD)	12.3 (1.27)
Admit %IBW (M, SD)	58.7 (5.61)
Discharge BMI (M, SD)	15.2 (0.85)
Discharge %IBW (M, SD)	72.8 (4.04)
ED Diagnosis (N, %)	
AN-BP	19 (38.8%)
AN-R	30 (61.2%)
Age of Onset of Illness (M, SD)	17.0 (5.34)
Duration of Illness in Years (M, SD)	14.8 (12.7)
Number of Psychiatric Comorbidities (M, SD)	1.98 (1.42)
Length of Stay in Days (M, SD)	30.6 (12.1)

Grip strength

At admission, 4% (N = 2) of patients exhibited normal grip strength for their sex and age in their right hand, and 10% (N = 5) in their left hand. At discharge, 10% of patients (N = 5) exhibited normal levels of grip strength in their right hand. The number of individuals who exhibited normal grip strength levels in their left hand (N = 5) remained the same as admission.

Correlations at admission

Regarding bivariate correlations at admission (see **Table 2**), right hand grip strength was negatively associated with CPFQ (r = -.31, p = .03). BDI-2 and self-reported cognitive functioning were positively associated (r = .68, p < .001), and CPFQ and Coding were negatively associated (r = -.26, p = .04). BMI was negatively associated with right hand grip strength (r = .56, p < .001) and left hand grip strength (r = .51, p < .001).

Change from admission to discharge

Regarding change from admission to discharge, all changes were statistically significant at the p < .001 level (see **Table 3**), with BMI, right and left hand grip strength scores and the Coding score significantly higher at discharge, and BDI-2 and CPFQ scores significantly lower at discharge. Except for patients aged 18-19 years old, whose average scaled score of 10 stayed the same, patients experienced an average increase of 1.83 on their Coding scaled score from admission to discharge, indicating clinically meaningful improvement of over a third of a standard deviation [39,40]. Scaled scores ranged from 7 to 12 at admission and from 9 to 13 at discharge.

Correlations among change scores

Regarding correlations of changes from admission to discharge (see **Table 4**), change in right hand grip strength was positively associated with change in left hand grip strength (r = .89, p < .001). Change in BDI-2 total score was positively associated with change in CPFQ total (r = .60, p < .001). Changes in BMI were not associated with changes in right hand grip strength (r = -.17, p = .23) or changes in left hand grip strength (r = -.21, p = .14).

Table 2. Correlations at admission.

	Grip Right	Grip Left	BDI-2 Total	CPFQ Total	Cognitive Performance
Grip Right	1				
Grip Left	.94**	1			
BDI-2 Total	-.24	-.24	1		
CPFQ Total	-.31*	-.25	.68***	1	
Cognitive Performance (Coding)	.15	.23	-.23	-.26*	1
BMI	.56***	.51***	.08	-.01	-.02

Note. ***p<.001; *p<.05

Table 3. Change from admission to discharge.

	Admission M (SD)	Discharge M, (SD)	Change t-value
Grip Right	14.54 (6.71)	18.65 (5.24)	t=9.34***
Grip Left	12.90 (6.54)	16.73 (4.91)	t=8.60***
BDI-2 Total	34.02 (12.39)	21.21 (13.86)	t=-8.21***
CPFQ Total	28.31 (7.15)	17.45 (7.21)	t=-9.45***
Coding	66.27 (17.15)	75.16 (16.35)	t=5.95***
BMI	12.3 (1.27)	15.2 (0.85)	t=15.82***

Note. ***p<.001

Table 4. Correlations of changes from admission to discharge.

	Δ Grip Right	Δ Grip Left	Δ BDI-2 Total	Δ CPFQ Total	Δ Coding
Δ Grip Right	1				
Δ Grip Left	.89***	1			
Δ BDI-2 Total	.13	.17	1		
Δ CPFQ Total	.11	.02	.60***	1	
Δ Coding	.09	.01	-.24	-.07	1
Δ BMI	-.17	-.21	.27	.27	.05

Note. ***p<.001. Δ represents admission-discharge change.

Table 5. Correlations of changes from admission to discharge split by BMI.

	Δ Grip Right	Δ Grip Left	Δ BDI-2 Total	Δ CPFQ Total	Δ Coding	Δ BMI
Δ Grip Right	1	.84***	-.23	-.07	.36	-.32
Δ Grip Left	.93***	1	-.04	.11	.20	-.51*
Δ BDI-2 Total	.50*	.42*	1	.75***	-.36	.10
Δ CPFQ Total	-.07	-.04	.38	1	-.13	.20
Δ Coding	-.07	-.11	-.17	-.03	1	<.01
Δ BMI	.06	.03	.32	.17	.05	1

Note. ***p<.001. Δ represents admission-discharge change. Correlations below the diagonal are for N=25 patients with BMI ≤ 12.41. Correlations above the diagonal are for N=24 patients with BMI > 12.41.

Correlations among change scores at different levels of BMI

A median split for BMI was used to group patients into lower (≤ 12.41) and higher (>12.41) admission BMI groups, with correlations among variables presented for both groups (see **Table 5**; below median BMI below diagonal, above median BMI above diagonal). While most associations remained similar across groups, the correlation between change in BDI-2 and changes in grip strength differed. Specifically, for patients at or below the median BMI, changes in BDI-2 were positively associated with changes in right hand grip strength ($r = .50$, $p = .01$) and left hand grip strength ($r = .42$, $p = .01$).

For patients above the median BMI, changes in BDI-2 were not associated with changes in right hand grip strength ($r = -.23$, $p = .28$) or left hand grip strength ($r = -.04$, $p = .85$). The correlation between change in CPFQ and change in BDI-2 also differed by BMI group. Specifically, for patients above the median BMI, changes in CPFQ were positively associated with change in BDI-2 and were not significant in the lower BMI group ($r = .38$). Additionally, among the higher weighted group, changes in BMI were negatively associated with change in left hand grip strength ($r = -.51$) and unrelated in the lower BMI group ($r = .03$).

Discussion

To our knowledge, this is the first prospective study to explore the relationship among grip strength, depression, and cognitive functioning in extremely malnourished patients with AN-R or AN-BP over the course of medical stabilization, and to explore how these variables might relate among those with the most severely low BMI. At admission, malnourished patients with AN, notwithstanding their young age, demonstrated significant impairment in grip strength, supporting findings of previous research [5]. The average age of patients was 32; however, they presented with grip strength scores of a 6- or 7-year-old girl [46]. Individuals with AN also reported BDI-2 scores in the severely depressed category, indicating high levels of cognitive, affective, and somatic concerns putting them at a higher risk of suicide and at a significantly greater likelihood to die compared to patients with AN without comorbid depression [1]. The average patient viewed their cognitive functioning as being markedly diminished at intake.

Grip strength and BMI were moderately and positively correlated at admission in that the lower the BMI, the poorer the grip strength. This is not surprising, given the connection between malnutrition and lower grip strength [7] and prior findings that AN patients at lower BMIs had worse grip strength than AN patients at a higher BMI [5,22]. Given that individuals with lower muscle strength and low BMI are at an increased risk of all-cause mortality [21], the findings from this study underscore the serious impact AN can have on a patient's health.

Within this sample of AN patients, grip strength was significantly impaired, and depression was severe. Though they may be independent markers of severity, various mechanisms have been hypothesized to explain the interrelatedness of poor muscle strength and depression. For example, poor physical functioning can negatively impact successful engagement in daily activities, leading to reduced feelings of achievement and negative self-appraisal, resulting in depression [26]. Reduced physical functioning can also limit mobility and the ability to socialize that then increases feelings of loneliness, which is associated with depression [47]. From a neurophysiological standpoint, reduced muscle strength is associated with an inflammatory profile [48], which is also linked to mood disorders [49].

Results from this study also showed that depression and self-reported cognitive functioning were moderately and positively correlated at admission in that the more depressed patients felt, the worse they rated their alertness, mental acuity, recall, and other features of cognition. This is not unexpected, given that depression and cognitive functioning are related [50,51]. However, it is concerning for this population, as AN is associated with higher rates of suicide [52] and executive functioning deficits increase the risk for suicide attempts [53]. Coding scores were negatively correlated with self-reported cognitive functioning, showing that patients who reported diminished cognitive and executive functioning abilities were indeed slower on their visual processing speed, short-term visual memory, and ability to sustain focus, indicating an ability for patients to accurately gauge their cognitive deficits.

Improvements from admission to discharge

BMI, grip strength, depressive symptoms, and cognitive functioning improved over the course of medical stabilization, notwithstanding that the average length of stay to achieve this was less than 4 weeks to achieve a BMI in the 14 kg/m^2 range. Yet, although improvement in grip strength was observed, patients continued to have grip strength measurements far below that of their age-matched peers at discharge. Therefore, they continued to be at increased risk for falls, fractures, morbidity, and mortality [7], demonstrating the importance of continued treatment and vigilance even after medical stability has been achieved. Levels of depression fell from severe to moderate over the course of medical stabilization, and patients felt that their cognitive functioning had improved, going from an average of "markedly diminished" to "normal" by the end of their hospital stay. Patients also demonstrated improved short-term visual memory and processing speed, with patients above the age of 19 showing meaningful improvement in their scaled score on the Coding test.

Overall, these findings highlight the value of selecting an appropriate level of care and the positive physical, psychological, and cognitive changes that are possible within weeks of medical hospitalization. As patients with AN often express hopelessness with regard to recovery, findings that depression, cognitive functioning, and strength improve significantly and relatively quickly may increase patient motivation and willingness to undergo further treatment. Given that the average BMI upon discharge remained low enough to necessitate continued treatment, future studies should explore improvements in grip strength, depression, and cognitive functioning throughout the course of weight restoration at lower levels of care, as these measures may continue to improve with continued weight gain [54]. Future research should also examine whether grip strength returns to normal after recovery from AN or whether grip strength remains impaired, as is the case, for instance, with bone mineral density [55].

Correlation among change scores

Among patients above the median split for BMI (>12.41), self-reported cognitive functioning and depression were positively associated, an expected finding given that subjective cognitive complaints have been reported in nearly 90% of acutely depressed patients [51]. This relationship was not found in the lower-weighted group, but we would argue that because the association was positive, it showed a similar relationship, though the magnitude differed. Among the higher weighted group, changes in BMI were negatively associated with change in left hand grip strength, whereas the two were unrelated in the lower BMI group. This could be due to the fact that the number of patients with normal grip strength in their left hand stayed the same from admission to discharge ($N = 5$) while their BMI increased, whereas at admission, fewer patients were found to have a normal grip strength in their right hand ($N = 2$) than at discharge ($N = 5$).

Among patients with extremely low BMI (≤ 12.41), grip strength was extremely diminished, and depression was extraordinarily severe, and both changed in the same direction from admission to discharge. Implications from these variables functioning as 'bedfellows' indicate that individuals with the absolute lowest BMIs are severely depressed and incredibly weak and are at increased risk for falls, fractures, suicide, and all-cause mortality. The validity of DSM-5 specifiers in AN has been called into question, with inconsistent findings across studies regarding whether meaningful differences are found in eating disorder pathology such as degree of weight/shape concern, psychiatric comorbidity, and functional impairment [56]. While no association between lower BMI and ED psychopathology is a common finding [57], increasingly higher levels of illness-specific functional impairment have been noted as a function of BMI [56]. We would argue that higher levels of functional impairment and depression were observed as a function of BMI severity and thus, categorizing AN patients based on weight may indeed have some merit.

Benefit of grip strength assessment

Patients with AN are often motivated to conceal weight loss through water loading, and/or surreptitiously adding weights to their clothes to falsely elevate their weights. Additionally, they often self-report that they are not functionally impaired, citing as evidence the fact that they are going to work, exercising, and engaging in activities of daily living [4]. This poses a challenge for practitioners trying to make recommendations for an appropriate level of care. Though exploring handgrip strength in AN is a nascent area and future studies are needed to properly validate the present findings, we would offer that grip strength could be a quick and objective marker of severity, and may lend credence, not only to provider recommendations for a higher level of care, but also to validate and demonstrate the severity of their condition.

The overall finding of poor grip strength among this cohort also lends credence to the importance of a multidisciplinary team for those with extreme AN [58], including the involvement of unit-dedicated physical therapists and occupational therapists. Assessment for the appropriateness of a gait belt, the use of wheelchairs and walkers, and the ability of a patient to stand in a shower without falling are all important considerations for these malnourished patients whose muscle strength is severely reduced.

Strengths and limitations

Strengths of this study include its prospective design and its novelty in being one of only a few studies exploring grip strength in AN, an understudied area important to explore given that grip strength is a biomarker in other populations, is associated with many important health markers, and is also a predictor of future health outcomes [7]. Another strength of this study was the inclusion of a lab draw of aldolase levels to control for this potential confounder of muscle weakness from neurogenic causes.

Limitations of the study include the relatively small sample size as well as only a small number of males that precluded analysis on gender differences with regard to grip strength, depression, and cognitive functioning. Handedness was not documented when measuring grip strength, and this is a limitation, as recording hand dominance is recommended during grip strength assessment [34]. However, the impact of hand dominance on grip strength readings varies across studies, with no consensus [33, 34], and stratified normative values for the Jamar dynamometer do not take handedness into account [34,58]. Though care was taken to include an objective measure of cognitive functioning, and no gold-standard neuropsychological test has been identified for use in AN [44], future studies should examine the utility and validity of the Coding measure for use in this population.

Conclusion

Individuals within the extreme category of AN exhibited extremely poor grip strength, severe depression, and impaired cognitive functioning at admission to a medical stabilization unit. Upon discharge, improvements were seen in all of these variables. Among the most low-weighted patients, grip strength and depression were significantly interrelated, highlighting that the most malnourished patients are at extreme risk for falls, fractures, and mortality, underscoring the need for these patients to be treated at an appropriate level of care. The utilization of grip strength assessments may offer a quick and objective measure of severity of AN and could help lend credence to recommendations for hospitalization among extremely ill, albeit often ambivalent patients.

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Conflict of Interest

The author declares that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

Author Contributions Statement

Kamila Cass: Conceptualization; data curation; investigation; methodology; project administration; supervision; writing – original draft; writing- review and editing. **Dan V. Blalock:** Data curation; formal analysis; writing – original draft; writing – review and editing. **Jamie Manwaring:** Data curation; investigation; writing – original draft; writing – review and editing. **Delaney Wesselink:** Data curation; writing – original draft; writing – review and editing. **Cheryl Lundberg:** Data curation; investigation; writing – original draft; writing – review and editing. **Philip S Mehler:** Conceptualization; writing – original draft; writing – review and editing.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Ethics Approval Statement

This study was approved by the Colorado Multiple Institutional Review Board (COMIRB).

Patient Consent Statement

Informed written consent was provided by all participants.

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