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Analysis of functional status and muscle strength in adults and older adults in an intensive care unit: a prospective cohort study

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Abstract *The aim of this study was to analyze and assess the association between functional status (FS) and muscle strength (MS) in young adults, adults and older adults in an intensive care unit (ICU). We conducted a prospective cohort study with 48 patients. FS was assessed using the Functional Status Score for the Intensive Care Unit (FSS-ICU) and MS was measured using the Medical Research Council Sum-Score (MRC-SS) and by testing handgrip strength (HS). The assessments were performed on awakening and ICU discharge. The data were analyzed using the Kruskall-Wallis, chi-squared, Wilcoxon and Spearman's correlation tests. FS and MRC-SS scores were higher on ICU discharge in all groups. Gains were lowest in the older adult group. HS was greater in both hands on ICU discharge in all groups except the adults. FSS-ICU on both awakening and ICU discharge was highest in the adults; HS-R was lowest in the older adults. There was a strong association between FS and MS in the young adults and adults. FS and MS showed progressive improvement during ICU stay. Gains in FS and MS on awakening and ICU discharge were lowest among the older adults. Important associations were found between these variables in all groups except the older adults. This can be explained by the multifactorial nature of illness and incapacity in this group.*

Key words *Health assessment, Intensive care unit, Physical function, Muscle strength, Older persons*

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Introduction

Technological advances and interdisciplinary intensive care have improved the survival of critical patients. Critically ill patients are subject to prolonged bed rest, leading to a decline in physical function, muscle strength and cognitive functioning[1-3]. In older patients, these changes may be more pronounced due to physical and mental limitations resulting from aging, which is a multifactorial process[4,5].

Immobility during hospitalization gives rise to early rapid loss of muscle in critical patients from different age groups, promoting a reduction in type II muscle fiber and contractile properties and an increase in inflammatory cytokines and muscle proteolysis[5-9]. These changes are responsible for around a 40% loss of muscle strength during the first week of immobilization in the intensive care unit (ICU), leading to ICU-acquired weakness (ICU-AW)[6,7].

Persistence of muscle weakness is associated with a reduction in aerobic capacity, negatively affecting quality of life and activities of daily living[2], and an increase in the number of re-hospitalizations and mortality[10-13]. A recent systematic review[3] highlighted that the assessment of physical function and muscle strength during ICU stay is extremely important and that these factors should be assessed early in order to identify patients potentially at risk of physical and functional impairment.

Some studies[10,13-19] have shown changes in physical function in critically ill patients. However, these studies do not describe changes in physical function by age group. Given the wide age range of patients admitted to ICUs, this information is extremely important to help optimize individualized treatment planning in order to ensure early treatment, including the ICU as the first stage of rehabilition[12]. The aim of this study was therefore to analyze functional status in young adults, adults and older adults on awakening and ICU discharge and assess the association between functional status and muscle strength.

Methods

Study characteristics

We conducted a prospective cohort study following the guidelines of the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement[20]. The study was carried out in the adult ICU of a public hospital in Ceilândia (Ceilândia Regional Hospital), Brasília, Federal District of Brazil between March 2015 and July 2016.

The study was approved by the Health Sciences Teaching and Research Foundation's research ethics commit. All the subjects and/or *legally responsible* parties were informed about the study protocol and signed an informed consent form.

Participants

Participants were recruited from critical patients using convenience sampling. Eligible patients were any patients of both sexes aged 18 years and over with a level of consciousness score of above 8 based on the Glasgow Coma Scale.

Patients with unstable fractures, motor and/or neurological impairments prior to ICU admission, wounds and/or other conditions that prevented them from sitting, and receiving palliative care were excluded.

Assessment protocol

The following clinical data was gathered from the electronic patient record system: sex; age; comorbidities prior to ICU admission; ICU admission diagnosis; clinical report of sepsis; body mass index (BMI); disease severity, measured by the Acute Physiology and Chronic Health Evaluation II (APACHE II); medications (length of time using corticosteroids, sedatives and vasoactive drugs); days on mechanical ventilation (MV); and pre-ICU and ICU length of stay.

All participants underwent an assessment of functional status (FS) and muscle strength (MS) on awakening and ICU discharge. The participants were divided into three groups: young adults, adults and older adults. Awakening was defined as the first day in which individuals responded to at least three of the following orders proposed by De Jonghe et al.[16]: "Open (close) your eyes", "Look at me", "Open your mouth and put your tongue out", "Nod your head", and "Raise your eyebrows when I have counted up to five".

The assessments were performed by a team of physical therapists, who were previously trained to administer the scales and assessment instruments. The ICU had 24-hour physical therapy care and all patients had at least two physical therapy sessions a day, in accordance with the IUC protocol.

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Functional status (FS) was assessed using the Functional Status Score for the Intensive Care Unit (FSS-ICU), a measure designed for ICU settings. Translated and adapted for use in Brazil, the instrument examines the patient's ability to perform the following five tasks: 1) rolling, 2) transfer from supine to sit, 3) sitting at the edge of the bed, 4) transfer from sit to stand, and 5) walking[21,22].

Participants were instructed to perform the tasks on the bed as independently as possible. If the patient was unable to complete the task, the examiner offered assistance. At the end of each movement, a score was assigned based on the assistance required to perform the task. Each task was scored on an eight-point scale ranging from 0 (unable to attempt or complete the task) to 7 (completely independent), resulting in a maximum total score of 35, where the higher the score, the better FS[21].

Muscle strength was measured using the Medical Research Council Sum-Score (MRC-SS) and handgrip strength (HS) measured using a *hand-held dynamometer*. The MRC-SS assesses six muscle groups: shoulder abductors, elbow flexors, wrist extensors, hip flexors, knee extensors and foot dorsiflexors[17,18].

The MRC-SS was initially performed with the patient's arm positioned against gravity. The examiner demonstrated the desired movement and then requested the patient to repeat the motion. If the patient was unable to perform the movement against gravity, the position was modified to reduce load[23]. An isometric hold was applied at the end of the range in order to test each grade of MS, as described by Parry[18]. Each muscle group was scored between 0 (total paralysis) and 5 (normal strength), with a minimum and maximum final score of 0 and 60, respectively[17]. A final score of less than 48 was considered indicative of ICU-AW[24].

HS was measured using a digital *dynamometer* (Jamar Plus®, Patterson Medical Ltd, Illinois, USA). The participants were sat with their elbow flexed at a 90-degree angle and forearms in a neutral position. The patients were then instructed to squeeze as hard as possible, making three attempts with each hand. The final measure was taken to be the mean of the three measures[19,24]. The examiner held the device and verbal encouragement was given during the attempts.

Statistical analysis

The categorical data were presented as total (n) and relative (%) frequencies and the continuous data were described as medians and interquartile range. The data were assessed for normality using the Kolmogorov-Smirnov statistic. All tests were bilateral and a significance level of 5% was adopted (a=0.05).

The overall sample was divided into three groups: young adults (≥18 to 39 years), adults (≥40 to 59 years) and older adults (≥60 years). To compare the clinical characteristics, FS and MS across the groups, we used the Kruskal-Wallis test with Muller-Dunn post-hoc testing for numerical variables and the Chi-squared test for categorical variables.

FS and MS on awakening and ICU discharge were analyzed using the Wilcoxon test. The correlation between the FSS-SS and MRC–SS and HS measures on awakening and ICU discharge was assessed using Spearman's correlation test.

Statistical analysis was performed using GraphPad Prism 5 for MAC and SPSS V.24 for MAC.

Sample size

Sample size was calculated based on the evolution of the FSS-SS and MRC-SS measures between awakening and ICU discharge, adopting a clinically significant difference of one-half standard deviation (effect size = 0.5), 95% significance level, power of 80% and dropout rate of 20%, resulting in a minimum sample of 40 patients.

Results

Forty-eight of the 54 eligible patients were assessed for FS and FM on awakening and ICU discharge: 16 young adults, 17 adults and 15 older adults. The median age (IQR) of the overall sample was 47 (36-62) years. The sample was predominantly male (62%) and the most common cause of admission to the ICU was respiratory disease (27%) (Figure 1).

The APACHE II score was higher among older adults than in adults and young adults [25 (19-29) *vs* 17 (14-24) *vs* 16 (14-19); p= 0.077] and the most common comorbidity was high blood pressure (100%). Frequency of use of invasive ventilation and ICU length of stay were similar across the groups (75%, 71% and 80%, respectively; p=0.828 and 9 (5-21) *vs* 11 (7-20) *vs* 12 (8-21); p=0.653).

Duration of MV was similar across groups [5 (0-12) *vs* 6 (0-11) *vs* 7 (31-12); p=0.824)].

Incidence of ICU-AW on awakening was higher in older adults (93%) than in young adults and adults (50% and 59%, respectively; p=0.026) (Table 1).

In the overall sample, there were significant differences in FSS-ICU [15 (7-24) *vs* 26 (16-32); p=0.001)], MRC-SS [44 (37-53) *vs* 52 (44-56); p=0.000)], HS-R [14 (11-25) *vs* 18 (11-25); p=0.002)] and HS-L [13 (8-22) vs 16 (10-23); p=0.004)] between awakening and ICU discharge. These measures show a gradual increase between awakening and discharge (Table 2).

The data show a considerable increase in FSS-ICU between awakening and discharge in the different age groups [17 (7-28) *vs* 21 (10-34), p=0.048; 18 (9-30) *vs* 32 (27-34), p=0.001; 11 (6-18) *vs* 23 (13-28), p=0.003)]. Similar results were found for MRC-SS [48 (32-56) *vs* 53 (36-60), p=0.050; 46 (39-56) *vs* 55 (45-56), p= 0.031; 40 (34-46) *vs* 48 (44-52), p=0.003)]. With regard to HS-R and HS-L, changes were observed in all groups except the adults (p=0.211; p=0.244). The right hand was the dominant hand in 75% of the young adults, 71% of the adults and 80% of the older adults. The data are shown in Table 2.

Significant differences in FSS-ICU were observed between young adults, adults and older adults both on awakening and on ICU discharge: awakening – 17 (7-28) *vs* 18 (9-30) *vs* 11 (6-18), p=0.040; discharge – 21 (10-34) *vs* 32 (27-34) *vs* 23 (13-28), p=0.013. HS-R was higher on awakening among all groups [17 (7-27); 18 (14-38); 12 (11-14); p=0.050] (Figure 2).

There was strong correlation between FSS-ICU and MRC-SS on both awakening (r=0.74; p=0.001) and discharge (r=0.75; p=0.001) in the overall sample. The findings also show a moderate correlation between FSS-ICU and HS-R and HS-L on both awakening and discharge: awakening – r=0.61; p=0.00 and r=0.57; p=0.001, respectively; discharge – r=0.57; p=0.007 and r=0.50; p=0.001, respectively.

A strong correlation was found between FSS-ICU and MRC-SS on awakening in young adults and adults. The correlation between FSS-ICU and HS-D was moderate in young adults and strong among adults, while the correlation between FSS-ICU and HS-L was moderate among both young adults and adults. The correlation between FSS-ICU and MRC-SS on ICU discharge was strong in young adults and adults, while the correlation between FSS-ICU and HS-R and HS-L was moderate and strong, respectively, in both these groups (r=0.80; p=0.001). Among older adults, the association between FS and MS was weak both on awakening and on discharge (Figure 3).

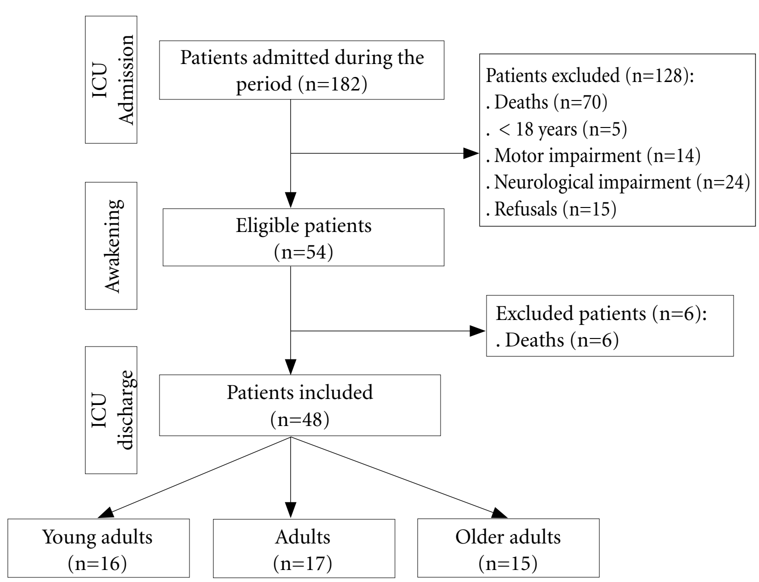

Figure 1. Study cohort flow diagram.

Source: Author's elaboration.

Table 1. Clinical and admission characteristics in the overall sample and different age groups during ICU stay.

Variables	Overall (n= 48)	Young adults (n=16)	Adults (n= 17)	Older adults (n=15)	p
Age. median (IQR)	47 (36-62)	31 (27-36)	47 (44-52)	65 (62-74)	<0.001
Male. n (%)	30 (62)	13 (81)	9 (53)	8 (53)	0.165
APACHE II score. median (IQR)	18 (14-27)	16 (14-19)	17 (14-24)	25 (19-29)	0.077
Comorbidities. n (%)					
High blood pressure	27 (56)	3 (19)	9 (53)	15 (100)	<0.001
Diabetes Mellitus	13 (27)	3 (19)	5 (29)	5 (33)	0.577
CHF	7 (15)	0	2 (12)	4 (27)	0.330
COPD	3 (6)	0	1 (6)	2 (13)	0.512
Stroke	4 (8)	0	1 (6)	3 (20)	0.199
CKD	6 (12)	1 (6)	3 (18)	2 (13)	0.506
BMI. median (IQR)	23 (22—29)	22 (21—28)	24 (22—30)	23 (22—29)	0.251
Causes of ICU admission. n (%)					
Respiratory	13 (27)	4 (25)	6 (35)	3 (20)	0.07
Cardiovascular	10 (20)	3 (19)	4 (23)	3 (20)	
Infection	8 (17)	3 (19)	2 (12)	3 (20)	
Post-operative	3 (6)	1 (6)	1 (6)	1 (7)	
Neurological	4 (8)	2 (12)	2 (12)	0 (0)	
Inflammatory	8 (17)	3 (19)	1 (6)	4 (26)	
Intoxication	2 (4)	0	1 (6)	1 (7)	
Medication use. median (IQR)					
Days corticosteroids	4 (0-9)	7 (0-12)	3 (0-9)	1 (0-7)	0.153
Days sedatives	3 (0-7)	4 (0-9)	2 (0-6)	4 (2-9)	0.499
Days vasoactive drugs	3 (0-8)	0 (0-7)	2 (0-8)	5 (2-11)	0.204
Sepsis n (%)	16 (33)	3 (19)	6 (36)	7 (47)	0.251
Use of MV. n (%)	36 (75)	12 (75)	12 (71)	12 (80)	0.828
Days MV. median (IQR)	6 (2-12)	5 (0-12)	6 (0-11)	7 (3-12)	0.824
Days pre-ICU. median (IQR)	2 (1-8)	3 (1-8)	2 (1-8)	3 (2-10)	0.509
Days ICU admission. median (IQR)	10 (7-20)	9 (5-21)	11 (7-20)	12 (8-21)	0.653
Dias until awakening. median (IQR)	7 (3-11)	4 (3-12)	7 (3-13)	8 (6-11)	0.439
ICU-AW on awakening. n (%)					
MRC-SS ≤48 points	32 (67)	8 (50)	10 (59)	14 (93)	0.026
Physical therapy. median (IQR)					
Motor. total sessions	19 (10-36)	10 (6-44)	19 (12-36)	21 (14-41)	0.499
Respiratory. total sessions	16 (10-38)	12 (6-49)	17 (11-36)	22 (14-41)	0.499

Data shown in medians and interquartile range (IQR). absolute frequencies (n) and percentage (%) with p-values for the following tests: Kruskal-Wallis with Muller-Dunn post testing and chi-squared test (significance level = p≤0.05). APACHE II: Acute Physiology and Chronic Health Evaluation System II; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease; CKD: chronic kidney disease; BMI: body mass index; ICU: intensive care unit; MV: Mechanical ventilation; ICU-AW: ICU-acquired weakness. MRC-SS: Medical Research Council Sum-Score.

Source: Author's elaboration.

Discussion

The findings show a gradual change in functional status and muscle strength in patients between awakening and ICU discharge. The older adults showed lower gains in physical function and muscle strength. Important associations were found between functional status and muscle strength among young adults and adults. These findings can help guide therapeutic actions ac-

Table 2. Assessment of functional status and muscle strength between awakening and ICU discharge in the overall sample and different groups.

Variables	Overall (n=48)			Young adults (n=16)			Adults (n=17)			Older adults (n=15)		
	Awakening	Discharge	p	Awakening	Discharge	p	Awakening	Discharge	p	Awakening	Discharge	p
FSS-ICU	15 (7-24)	26 (16-32)	0.001	17 (7-28)	21 (10-34)	0.048	18 (9-30)	32 (27-34)	0.001	11 (6-18)	23 (13-28)	0.002
MRC-SS	44 (37-53)	52 (44-56)	0.000	48 (32-56)	53 (36-60)	0.050	46 (39-56)	55 (45-56)	0.031	40 (34-46)	48 (44-52)	0.003
HS-R	14 (11- 25)	18 (11-25)	0.002	17 (7-27)	21 (11-27)	0.009	18 (14-38)	18 (13-27)	0.211	12 (11-14)	16 (10-19)	0.023
HS-L	13 (8-22)	16 (10-23)	0.004	14 (6-28)	16 (9-31)	0.009	18 (10-27)	18 (11-24)	0.241	11 (6-16)	12 (9-21)	0.019

Data shown in medians and interquartile range (IQR). Wilcoxon test, P-value, significance level = $p \leq 0.05$.

Legend: FSS-ICU: Functional Status Score for the Intensive Care Unit; MRC-SS: Medical Research Council Sum-Score; HS-R:handgrip strength right hand; HS-L: hand grip strength left hand.

Source: Author's elaboration.

cording to the specific clinical needs of each age group, indicating that older adults need tailored preventive therapy to minimize the negative effects of ICU admission.

Functional decline in critical patients during ICU admission, regardless of age group, is a prominent topic in the literature. Previous systematic literature reviews[2, 25-27] highlight impairment of cardiovascular and musculoskeletal systems, posing a potential health risk, meaning that early identification of these problems is important to ensure timely interventions.

Our sample was predominantly male, which is consistent with the findings of international studies[21,28] with critical patients in ICUs. Men show low adherence to preventive and curative measures because they take less care of their health than women as they dedicate themselves more to work, therefore tending to seek care in more critical situations when symptoms are more severe[29,30].

In addition, from a cultural perspective, men tend to be taught from a young age to display their masculinity, strength and virility, meaning that physical frailty and being absent from work does not cause as much unease among women as it does in men[31].

Although chronic comorbidities such as high blood pressure and diabetes mellitus were present in all age groups, the prevalence of these conditions was higher among the older adults. This may be attributed to an increase in life expectancy in recent years, directly affecting the prevalence of chronic diseases. The latter are key factors in cardiovascular risk, which can lead to an increase in fatal and non-fatal cardiovascular outcomes, influencing hospital admission rates among older adults[32,33].

Most of the patients in our study needed mechanical ventilation. Duration of ventilation was longer among the older adults. These findings are similar to those reported by Dietrich et al.[34], who showed that mean duration of ventilation among older adults (61-79 years) was 8.0 ± 11.2 days. The findings of the current study show that mean ICU length of stay was above seven days, which is consistent with the findings of international and Brazilian studies[18,29,34,35]. This is explained by illness severity and patient condition, meaning that length of stay can range from hours to weeks, depending on patient response to therapy[27].

In older adults, immobility in the ICU (associated with the course of the disease and age-related physiologic changes) can result in significant limitations that lead to loss of respiratory muscle strength, making critical patients more susceptible to respiratory complications, prolonged use of MV, dysphagia and post-extubation foreign body aspiration, ultimately resulting in increased mortality and health care costs[36]. According to Yanping Ye et al.[37], mean daily ICU costs per patient can be up to US$1,212. Therefore, although MV may be necessary, it is important to seek strategies that optimize its use in order to minimize potential complications.

The prevalence of ICU-AW in the current study was high in older adults. This is a common complication and recurring problem in the acute phase of the disease in this age group[38]. Evidence[2,29,39-41] shows that ICU-AW reduces physical

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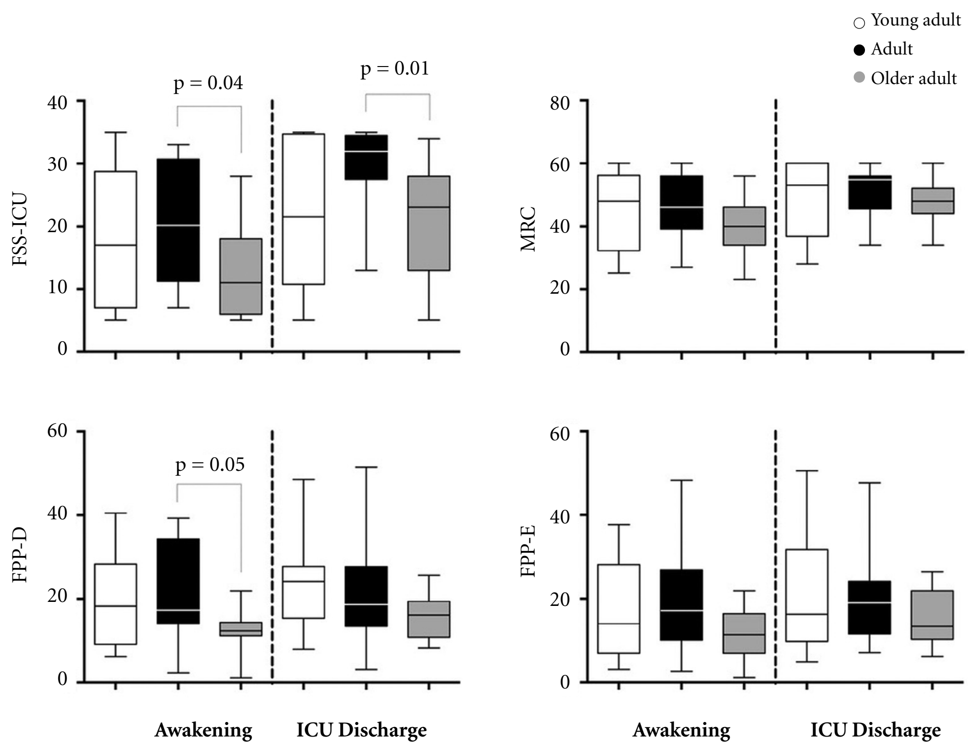


Legend: FSS-ICU: Functional Status Score for the Intensive Care Unit; MRC-SS: Medical Research Council Sum-Score; HS-R: handgrip strength right hand; HS-L: hand grip strength left hand. Kruskal-Wallis test - P-value, significance level = p≤0.05.

Figure 2. Analysis of functional status and muscle strength on awakening and ICU discharge in the young adult, adult and older adult groups.

Source: Author's elaboration.

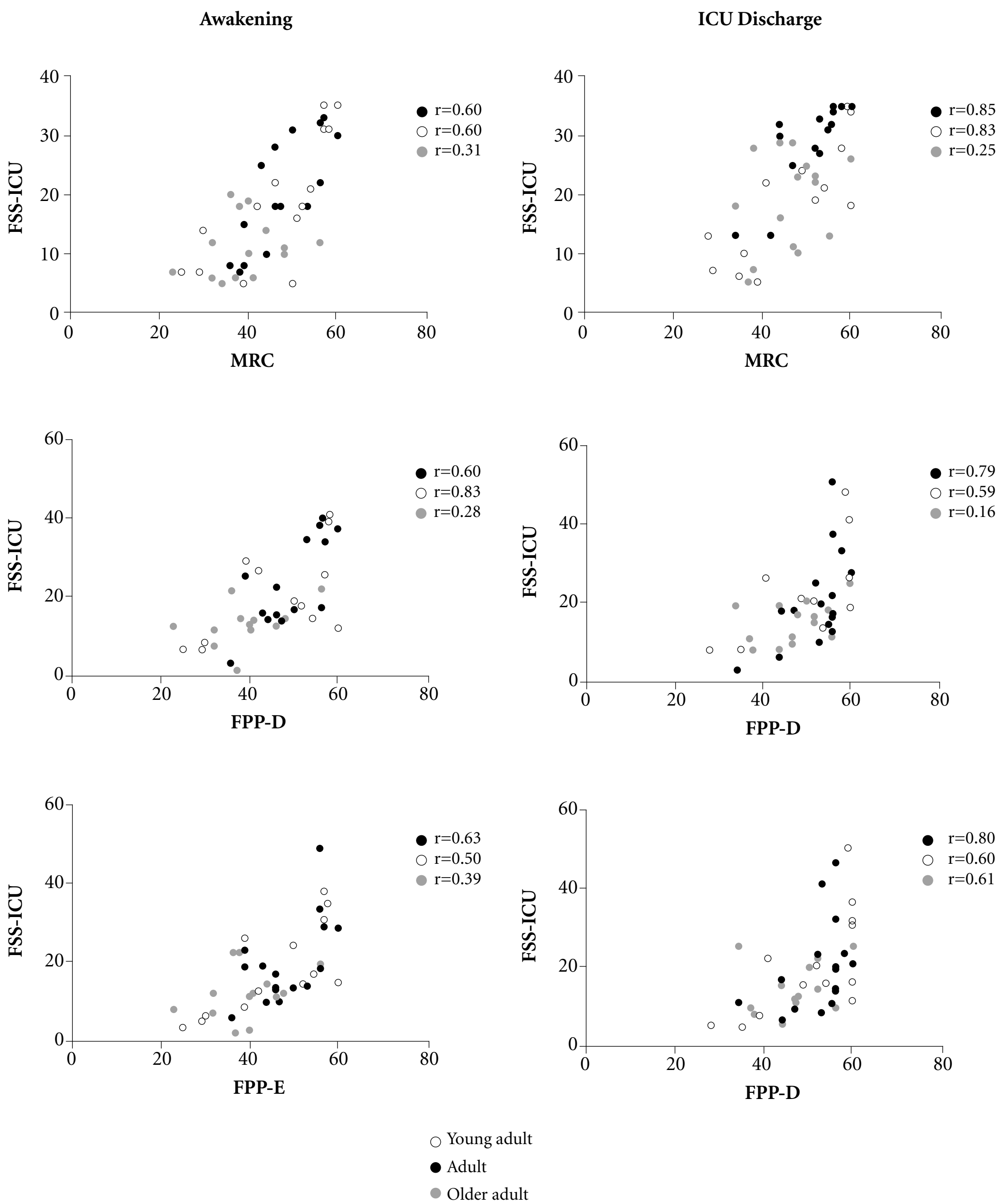
function and bedside mobility and can be a predictor of poor functional health status for up to one year after ICU discharge. Patel et al.[42] demonstrated that both increasing age and severity of illness are risk factors for developing ICU-AW.

Decline in physical and mental functioning in comparison with performance prior to admission is particularly evident in critically ill patients. These changes can be accentuated by prolonged ICU length of stay, use of MV, sepsis, multiple organ dysfunction, immobility, the use of systemic corticosteroids, ICU-AW, slow recovery from lung injury and age[11-14,16,26,28].

Reduced functional status was observed on awakening, followed by a gradual increase in parameters up to ICU discharge. These findings were similar to those found in previous research assessing functional status and muscle strength in critical patients using FSS-ICU, MRC-SS and dynamometry[14,15,43,44]. These studies showed a considerable increase in physical function and muscle strength during ICU stay. A study by Zanni et al.[14] reported a four-point increase in the FSS-ICU score between the pre-hospitalization baseline and ICU discharge, while Thrush et al.[15] showed that median cumulative FSS-ICU scores increased by five points. Furthermore, an international clinimetric assessment of FSS-ICU involving the United States, Australia and Brazil found an effect size of 2.02 from awakening to ICU discharge.

Our findings show a progressive increase in muscle strength during ICU stay, with slow progress towards achieving prior baseline strength[45]. A recent study by Dietch et al.[34] showed differences in MRC-SS and HS in older persons aged between 61-79 years and ≥80 years between ICU admission and discharge.

Functional decline was more accentuated in the older adults because aging is a contributing



Legend: FSS-ICU: Functional Status Score for the Intensive Care Unit; MRC-SS: Medical Research Council Sum-Score; HS-R: handgrip strength right hand; HS-L: handgrip strength left hand. Spearman's correlation test.

Figure 3. Analysis of correlation between functional status (FSS-ICU) and muscle strength (MRC-SS, HS-R and HS-L) in the different groups.

Source: Author's elaboration.

factor. In this regard, key ICU risk factors related to immobility give rise to an imbalance between muscle protein synthesis and degradation. This in turn is associated with myofibril necrosis, leading to a reduction in muscle mass and bone mineral density[46,47].

However, the estimate of improvement in functional status and muscle strength in the old-

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er adults was high, demonstrating potential improvement in frailer individuals. This shows that developing preventive strategies in this age group is important to provide significant beneficial effects[47]. Preventive and curative measures should therefore focus on clinical strategies that have an impact on modifiable characteristics, seeking to adopt an individualized approach directed at maintaining or gaining global muscle strength, mobility and physical function according to patients' specific needs[48].

FSS-ICU showed a correlation with the two measures of muscle strength on both awakening and ICU discharge. Similar results were found in the literature[21,49], with studies pointing to an association between FSS-ICU and MRC-SS, HS, ICU Mobility Scale, Activities of Daily Living (ADL) and Physical Function in Intensive Care Test-scored (PFIT-s) scores. However, there was a week association between physical function and muscle strength in the older adults. In this regard, it is probable that functional decline in older adults does not occur only due to a reduction in muscle strength, but also as result of deficiencies in multiple body systems that may be related to illnesses diagnosed prior to admission[50,51].

This study has some limitations. The data do not show functional status and muscle strength prior to ICU admission. The fact that the admissions were emergency admissions made it difficult to assess this information, thus limiting comparisons between the measures and baseline data. Although we achieved the minimum sample size, caution should be taken when generalizing the findings to other ICUs due to the specific characteristics of the study sample.

Future observational and interventional studies should be conducted with older critically ill patients in different ICU settings to explore other factors associated with functional decline in older adults. The findings of such studies can inform early interventions tailored to the specific needs of frailer patients in order to minimize the adverse effects of ICU admission and post-ICU discharge, promoting an independent return to activities of daily living.

Conclusion

Functional status and muscle strength showed progressive improvement during ICU stay. The older adults showed a smaller gain in functional status and muscle strength after awakening. There was an important association between these variables in the young adults and adults, characterizing an interaction between the different domains of the functional status of the adults. With regard to the older adults, the variables were not correlated due to multimorbidities and the multifactorial nature of illness and incapacity in this group.

Collaborations

GS Martins contributed to study conception, data collection and interpretation, and writing the article. SV Toledo contributed to data collection. JML Andrade and EY Nakano performed the statistical analysis. LPS Paz contributed to statistical analysis and writing the article. R Valduga contributed to study conception. G Cipriano Júnior. G contributed to revising the article. GFB Cipriano contributed to study conception, writing and revising the article and approving the final version to be published.

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