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THE EFFECT OF AGE UPON THE INTERRELATIONSHIP OF BMI AND INPATIENT HEALTH OUTCOMES

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Abstract: *Objectives:* There is growing evidence that the relationship between body mass index (BMI - defined as weight in kilograms divided by height in metres squared) and patient outcomes is age-dependent; specifically, a raised BMI may have a protective effect in older adults. This has been demonstrated clearly in the community setting; less clear is the effect of age on this relationship in the inpatient setting. *Design, setting, participants and measurements:* Retrospective analysis of 22,903 electronic records for patients discharged from two large public hospitals in South Australia between January 2015 and September 2018 inclusively. Records were retained if the patient's height and weight had been recorded during the admission, BMI was between 10-99 kg/m^2 and it was the patient's first admission during that time. Patients were grouped by BMI (<18.5 kg/m^2 ("underweight"), 18.5-24.9 kg/m^2 ("normal weight"), 25-29.9 kg/m^2 ("overweight"), >30 kg/m^2 ("obese")) and age (18—59 years, 60-79 years, > 80 years); for each group we measured the relative stay index (RSI) (actual length of stay divided by predicted length of stay), death in hospital and composite adverse outcome after discharge (unplanned readmission within 30 days and/or death within 30 days). *Results:* Underweight patients across all age groups generally experienced significantly poorer outcomes compared to those not underweight. In those aged 18-59 years there were no significant differences in outcomes between the normal weight, overweight and obese groups. In those aged 60-79 years overweight patients had a significantly reduced risk of RSI > 2 compared to those of normal weight (p=0.014), and both overweight and obese patients had a significantly reduced risk of adverse outcome after discharge when compared to those of normal weight (p=0.028 & p=0.009 respectively). In those aged 80 years or older, both overweight and obese patients had a significantly reduced risk of adverse outcome after discharge when compared to those of normal weight (p=0.028 & p=0.013 respectively), and obese patients had a significantly reduced risk of inpatient mortality and RSI >2 when compared to those of normal weight (p=0.027 & p=0.037 respectively). *Conclusion:* A BMI > 25 kg/m^2 in older patients is associated with reduced risk of prolonged admission, inpatient mortality and adverse outcomes following discharge. This adds to growing evidence that age-specific BMI guidelines are required for adults because the healthiest BMI in the older hospital patient is seemingly not in the range 18.5-24.9 kg/m^2.

Key words: Obesity, elderly, inpatient, BMI.

Introduction

The World Health Organisation (WHO) states that, for adults, a normal, or ideal, body mass index (BMI) is one between 18.5-24.9 kg/m^2, a BMI of 25-29.9 kg/m^2 is classified as being overweight, and a BMI of greater than or equal to 30 kg/m^2 as being obese (1). Notably, these criteria are deemed appropriate across all adult age groups. In 2013, it was estimated that 18% of men and 20% of women were obese worldwide (2).

The generally harmful effect of obesity on both the community and inpatient population has been well demonstrated in the past. Obesity has been reported as being the 6th most significant risk factor in terms of contribution to worldwide disease burden and has over 20 known associated comorbidities, primarily relating to cardiovascular disease, metabolic disease, cancer, respiratory disease, psychosocial and musculoskeletal disease (3-5). When compared to those with a healthy BMI, obese patients typically have an increased length of stay, increased rates of ICU admission and increased hospital readmission rates, and are at increased risk of wound complications, ulcers, respiratory infections, acute renal injury and inaccurate medication dosing (3-4, 6-7). The effect of obesity on in-hospital mortality is conflicting, with studies variably demonstrating either a positive or negative correlation, or no correlation at all (4, 7-13).

There is growing evidence to suggest that advanced age alters the effect of obesity on health outcomes. The definition of an older patient is variable within the literature but typically includes those older than 65 years. Multiple studies have demonstrated that the morbidity and mortality associated with obesity are lessened in the older person; some even report a mortality/morbidity advantage with increased weight (5, 14-19). One systematic review indicated that the majority of studies indicate the best outcomes for older people in the community are experienced by those with a BMI between 25-35 kg/m^2; however this is dependent on the outcome measured and sex (5). Overall, it appears that age significantly alters the relationship between BMI and health outcomes in the community. What remains less clear is the effect of age on this relationship in the acutely unwell – i.e. the inpatient setting. Our study aimed to assess the effect of age on the relationship between obesity and health outcomes in the inpatient setting by studying those who experience an unplanned (i.e. emergency)

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Table 1

Age: 18-59 (n=7,845)				
BMI (kg/m^2)	<18.5	18.5-24.9	25-29.9	>30
N	458	2747	2215	2425
RSI > 2	119 (28.5%)	643 (25.2%)	546 (26.5%)	598 (26.4%)
Died in hospital	7 (1.5%)**	11 (0.4%)	7 (0.3%)	14 (0.6%)
Adverse outcome 30 days post-discharge	81 (17.7%)**	345 (12.6%)	249 (11.2%)	304 (12.5%)
Age: 60-79 (n=8,126)				
N	435	2486	2602	2603
RSI > 2	101 (24.8%)	575 (24.3%)	510 (20.5%)*	562 (22.5%)
Died in hospital	15 (3.4%)**	34 (1.4%)	37 (1.4%)	29 (1.1%)
Adverse outcome 30 days post-discharge	117 (26.9%)**	425 (17.1%)	373 (14.3%)**	384 (14.8%)**
Age: >80 (n=6,932)				
N	634	3126	2096	1076
RSI > 2	120 (19.4%)	594 (19.9%)	375 (18.6%)	181 (17.5%)*
Died in hospital	27 (4.3%)**	85 (2.7%)	54 (2.6%)	16 (1.5%)*
Adverse outcome 30 days post-discharge	160 (25.2%)**	651 (20.8%)	384 (18.3%)*	186 (17.3%)*
Overall N (%)	**1527 (6.7%)**	**8359 (36.5%)**	**6913 (30.2%)**	**6104 (26.7%)**

* P < 0.05, ** P < 0.01, cf the group BMI = 18.5-24.9 kg/m^2

admission. Better understanding this relationship will assist in determining the prognosis for older patients with a BMI above the normal range in the face of an emergency hospital admission. This work will also add to the ongoing debate regarding recommended weight in the older adult and the appropriateness of weight-loss interventions in this group.

Materials and methods

Electronic records were selected for adult (aged > 18 years old) separations from the two largest public hospitals in Adelaide, South Australia, across the period January 2015 to September 2018 inclusive. Records were retained if the admission was unplanned, the patient's height and weight had been recorded during the admission, and the resultant BMI value was between 10 and 99 kg/m^2. The dataset was then limited to one (the first) admission per patient.

The dataset contained the following fields: hospital ID, patient ID, age, sex, height, weight, date of admission, admission type, expected length of stay (LOS), actual LOS, date of separation, and date of death. Using these data we were able to determine the patient's BMI (kg/m^2). For those cases where a subsequent unplanned readmission (to any of the 8 major public hospitals in Adelaide) was found, we calculated the number of days from hospital separation to that subsequent admission; for those cases with a date of death recorded, we calculated the number of days from hospital separation to death. We also calculated the "relative stay index" (RSI), as actual LOS divided by the LOS expected for a patient of similar age and complexity with a diagnosis from the same diagnosis related group(as defined by ICD-10) for those cases where the expected LOS was greater than zero (20).

We then derived a composite measure of adverse outcome after discharge, identified as such if either of the following outcomes occurred; the patient died within 30 days of leaving hospital, or the index admission was followed by an unplanned admission (for any reason) within 30 days of discharge.

We grouped BMI scores as per WHO guidelines, namely: <18.5 kg/m^2 ("underweight"), 18.5 to 24.9 kg/m^2 ("normal weight"), 25 to 29.9 kg/m^2 ("overweight") and >= 30 kg/m^2 ("obese"); we note that the terminology for these groups is as per the WHO guidelines and does not necessarily indicate effect on health. We grouped age as follows: 18 to 59 years old ("youngest"), 60 to 79 years old ("older"), and >= 80 years old ("oldest"). We defined our three outcomes of interest as: RSI > 2, death in hospital during the index admission and adverse outcome after discharge.

Statistical analyses were performed using Stata version 15 (Stata Corporation). Multivariable logistic regression was used to compare predicted values of the different BMI categories after adjusting for age group. Data are presented as counts and rates (percentages), with statistical significance reported where $p < 0.05$.

Results

The initial number of hospital separation records extracted was 276,324; 91% were then removed as either the patient's

height and/or weight had not been recorded, or the resultant BMI was outside of the range 10 to 99 kg/m^2, leaving an intermediate dataset of 26,202 records. In the next step 13% were removed after limiting the dataset to the first admission per patient, leaving a final dataset of 22,903 records.

Irrespective of the age category, those considered underweight carried a significantly increased risk of experiencing two of the three outcomes of interest compared to those not underweight (Table); prolonged LOS was no more likely in the underweight in any of the three age categories.

In the youngest age cohort, there were no statistically significant differences in rates of occurrence of any of these three outcomes between the normal weight, overweight and obese groups (Table).

In the older age cohort, overweight patients had significantly reduced risks of RSI >2 ($p<0.05$) and of adverse outcome after discharge ($p<0.01$) when compared to normal weight patients (Table). Obese patients in this age category also had a significantly reduced risk of adverse outcome after discharge ($p<0.01$) compared to normal weight patients, but their risk of prolonged LOS or death in hospital was no different to the normal weight group.

In the oldest age cohort, overweight patients were at significantly reduced risk of adverse outcome after discharge ($p<0.05$) but the same risk of inpatient mortality and RSI >2 when compared to the normal weight group (Table). Obese patients in this age category were at significantly reduced risk of adverse outcome after discharge ($p<0.05$), inpatient mortality ($p<0.05$) and RSI >2 ($p=0.037$) when compared to the normal weight group (Table).

Discussion

This study was performed to assess the effect of age upon the relationship between BMI and adverse patient outcomes. Using retrospective data from the two largest South Australian public hospitals, our findings suggest that this relationship is influenced by the age of the patient, noting the exception that patients classified as underweight had significantly worse outcomes across all age groups; such findings in the underweight have been consistently seen in other studies, and we have included these data from underweight patients in our analysis to allow a comparison of the risk of poor outcomes in the overweight and obese inpatient (21-23).

Worse outcomes at either extreme of BMI (a 'u-shaped' curve) have been demonstrated in numerous studies (5, 14-15, 22, 24-25). For patients aged between 18-59 years we saw no significant difference in the risk of experiencing any of these adverse outcomes when the overweight and obese groups were compared to the normal weight group. In older patients though, those with the lowest risk for a poor outcome from a hospital admission were not the patients with a normal BMI. For this reason, we believe the use of the terms "normal" and "healthy" BMI needs re-examination in the older hospital patient.

For patients 80 or older, we found no sign of greater risk of poorer outcomes in the overweight or obese. In fact, patients in this age group with a BMI > 30 kg/m^2 consistently had the lowest risk of an adverse outcome. We should note however that our study did not distinguish obese individuals from morbidly obese individuals.

Overall, we found that, as patients age, the BMI associated with the best hospital outcomes lies above the normal range. Other studies have demonstrated protective effects of higher BMI in the older adult in the community/longitudinal setting; our study suggests that this effect also applies to older patients, hospitalised after an emergency admission, most of whom would be acutely unwell.

To what mechanisms can we attribute these findings?

An important predictor of hospital outcomes in the older patient is the quantity of lean body mass (LBM), also known as fat-free mass. In essence, greater LBM is generally predictive of better hospital outcomes. A related concept is sarcopenia, the degenerative loss of skeletal muscle mass and strength associated with aging (26-29). Sarcopenia has been shown to be an independent predictor of in-hospital complications, post-operative complications, hospital LOS, health-care cost, frequency of hospital admissions, and hospital mortality (14, 28, 30-35). Preservation of LBM results in better hospital outcomes overall; those with greater LBM have, on average, greater leg strength, walking speed and functional status (36). Loss of LBM results in loss of functional performance (36-37), and has also been shown to result in impaired immunocompetence and metabolism (38).

Of note, although sarcopenic obesity (i.e. the co-existence of obesity with sarcopenia) is a relatively common phenomenon with notably poor outcomes, the incidence of sarcopenia is lower in the obese than in those with normal BMI (26, 29, 34, 39-41). Furthermore, weight loss almost invariably results in loss of LBM and skeletal muscle mass, even in the presence of dietary and activity modifications (36-37, 42-47).

Overweight, older adults appear to generally have better outcomes following hospitalisation than normal weight, older patients. Obese adults of all ages have greater quantities of adipose tissue, and in times of caloric deficit (such as when acutely unwell) lose comparatively less LBM (20-30% vs >35%); this is the concept of the obese having greater energy reserves in times of physiologic stress (47). Furthermore, obese adults typically have greater underlying LBM, muscle mass and limb strength (47-50). For these reasons, one could hypothesise that high BMI is protective in older patients at least in part due to greater preservation of LBM. Large studies with body composition analysis are required to further explore this theory.

As mentioned above, studies on the relationship between BMI and hospital outcomes and post-intervention outcomes have drawn varying conclusions. Some have found obesity associated with reduced inpatient mortality, whereas others have shown either no association between obesity and mortality or increased mortality risk with obesity (4, 7-13). Other

outcomes such as unplanned re-admission, prolonged LOS, intensive care unit (ICU) admission and ICU mortality have been variably shown to be increased, unchanged or reduced by obesity (4, 7-13, 51-53). There has also been conflicting evidence regarding the impact of obesity on post-surgical complications; a selection bias towards healthier obese patients for surgical treatments is a likely contributor (the so-called "obesity paradox") (54-63). Our results suggest that the relationship between BMI and adverse hospital outcomes is age-dependent; by implication this suggests that the ideal BMI to lower the risk of adverse hospital outcome differs across age groups, and so any study investigating outcomes in an obese population should analyse by age groups or risk significant bias in its findings. Failure to adjust for age may partially explain the current conflict in the literature.

There is a view that recommends weight loss interventions (including dietary, exercise, pharmacological and surgical) in those aged over 60 and sometimes even in those aged over 80 (64-66). The rationale for this view typically includes management of metabolic disease and improvement in functional and psychological status (64, 66-68). While there is evidence that lifestyle interventions can improve mobility in the obese elderly, there are few studies that have demonstrated clear improvements in other outcomes or as a result of other forms of intervention (65,68-70). In addition, of the studies focussed on the elderly, many of these assess a relatively young group of older patients i.e. patients predominantly in their 60s (71-73). Overall, there is little evidence that weight loss interventions in the elderly achieve the same improvements generally found in the younger adult population; this seems particularly so for patients older than 70 (65, 67, 69).

Our study assessed outcomes in patients categorised according to BMI. Multiple studies have demonstrated that BMI is a sub-optimal marker of body composition, and that other anthropometric tests (such as central adiposity, waist circumference, lean body mass/adipose mass and weight velocity) may have greater utility (74). However, the use of advanced body composition techniques has been shown to be little or no better at predicting disease risk than BMI, a far more easily obtained measure, and therefore we feel that its application in this clinical context is appropriate (75).

A possible limitation of this study is that some of the observed effects may be due to bias. Examples of potential bias would include survival effect (i.e. those obese who survive into old age being those who are protected in some way against the varying complications of obesity) and reverse causation (i.e. concurrent illness resulting in unintentional weight loss) (5, 76). It is also notable that only 9% of patients admitted to hospital during our study had accurately recorded BMI measurements, despite the ease with which these data can be collected. This may indicate that weight remains an undervalued consideration in the processes of care for patients within the hospital system, despite the growing awareness of its influence upon patient outcomes (3). We also note that the proportion of patients in each BMI category in our study was similar to that of a recent study in Western Australia that measured the BMI of 96% of all of their patients on one particular day (specifically 8% underweight, 37% healthy BMI, 32% overweight, 23% obese), and so, despite our low rate of capture of BMI data, our study may in fact reasonably represent the patient population of Australian hospitals (77).

Conclusion

Other studies have demonstrated that a higher BMI is favourable in the elderly in the community setting (5, 15, 29,78-79); our study suggests that this is also true in the acutely unwell. We found that in older patients a higher BMI is associated with lower in-hospital mortality, fewer unexpectedly long admissions and fewer post-discharge complications. Overall, this study lends support to a growing view that current BMI guidelines for adults should be made age-specific (5, 80-81). We suggest the observation that the association between BMI and patient outcomes is age-dependent may partially explain the varied findings across studies assessing obesity and patient outcomes; we believe the age of the patient needs to be considered in the design of future studies in this area. Where practical, further research studies should also consider quantifying body composition beyond the relatively crude BMI measure.

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Conflict of Interest: All authors declare there were no conflicts of interest involved.

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