Predictors of treatment outcome in persons with anorexia nervosa: On the practice of regressing body mass index at the end of treatment on body mass index at baseline

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Data availability statement

The data and code with which the results reported here can be reproduced can be accessed at https://osf.io/9v3fk.

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None.

Abstract

Objective: It is often stated that higher body mass index (BMI) at the beginning of treatment predicts a better outcome at the end of treatment in persons with anorexia nervosa (AN). However, this interpretation is based on the between-persons relationship of BMI at the two measurements, which primarily reflects the fact that the rank-ordering of persons according to their BMI is quite stable over time. In contrast, lower BMI at baseline relates to larger BMI change, which primarily reflects the fact that the variance of BMI at the end of treatment is larger than at baseline. This study aimed to demonstrate these relationships empirically and cautions against interpreting BMI at baseline as a predictor of BMI at discharge or BMI change.

Method: Changes of BMI from admission to discharge were analyzed based on 4863 persons with AN (97% female) who received inpatient treatment between 2015 and 2024.

Results: BMI at admission positively related to BMI at discharge (r = .55) but negatively related to BMI change from admission to discharge (r = −.39).

Discussion: While it is true that higher BMI at baseline is associated with higher BMI at the end of treatment, lower BMI at baseline actually relates to a larger weight gain during treatment. Yet, concluding that the treatment is more effective for patients with low or high BMI at baseline would be incorrect in either case as the independent and dependent variables are the same variable measured at different time points.

Public significance statement

It is often stated that higher body weight at the beginning of treatment predicts a better outcome at the end of treatment in persons with anorexia nervosa. Yet, while it is true that patients that weigh more at the beginning of treatment also weigh more at the end of treatment, patients that weigh less at the beginning of treatment actually gain more weight during treatment. Yet, ascribing these effects to a person’s different responding to the treatment would be wrong in either case.

Introduction

Anorexia nervosa (AN) is an eating disorder marked by significantly low body weight, which is accompanied by behaviors aimed at reducing energy intake (e.g., restrictive eating, purging) or increasing energy expenditure (e.g., excessive exercise), typically associated with a fear of weight gain. As low body weight is the core symptom of AN, a lower body mass index (BMI, kg/m^2) indicates higher severity in both the DSM–5 (American Psychiatric Association, 2013) and ICD–11 (World Health Organization, 2022). Accordingly, weight restoration usually is the primary goal in AN treatment (Barko & Moorman, 2023).

When examining predictors of treatment outcome in persons with AN, BMI at the beginning of treatment is often cited as one of the most robustly found predictor variables such that higher BMI at the beginning of treatment relates to a better treatment outcome or, vice versa, lower BMI at the beginning of treatment relates to a poorer treatment outcome (Gorrell et al., 2023). For example, it has been reported that premorbid BMI predicts BMI at the beginning of treatment, which in turn predicts BMI at the end of treatment, which in turn predicts BMI at 1-year follow up (Föcker et al., 2015). A problem with this interpretation is that when the same variable is measured at two time points and the later time point is regressed on the earlier time point, such an analysis does not test any changes over time.

We illustrate this with a recent study that examined whether weight suppression—the difference between a person’s highest and current body weight—predicted weight change in persons with AN (Calugi et al., 2023b). Higher weight suppression has consistently been found to predict larger weight gain both in non-clinical samples and in persons with eating disorders (Lowe et al., 2018; Meule et al., 2022; Meule & Platte, 2018). Among other analyses, Calugi et al. (2023b) regressed BMI at the end of treatment on weight suppression but excluded BMI at the beginning of treatment as independent variable because of multicollinearity concerns. The coefficient for effect of weight suppression on BMI at the end of treatment was *negative*, indicating that *higher* weight suppression related to *lower* BMI at the end of treatment. Because of this, the authors then discussed that their results were not in line with previous findings that showed that higher weight suppression predicts larger weight gain (Calugi et al., 2023b).

The crucial issue is that the authors actually did not test whether weight suppression relates to weight change as this would have required to include BMI at the beginning of treatment as independent variable (Meule, 2023). When the authors reanalyzed their data this way, the coefficient for the effect of weight suppression on BMI at the end of treatment was now *positive*, indicating that *higher* weight suppression related to *larger* weight gain—in line with findings from other studies (Calugi et al., 2023a). The coefficients for the effect of weight suppression on BMI at the end of treatment have opposite directions because the two analyses answer different questions. A negative coefficient when regressing BMI at the end of treatment on weight suppression indicates that higher weight suppression relates to lower BMI at the end of treatment, irrespective of any changes in body weight over time. A positive coefficient when regressing BMI at the end of treatment on both weight suppression and BMI at the beginning of treatment indicates that higher weight suppression relates to higher BMI at the end of treatment when controlling for BMI at the beginning of treatment and, thus, to larger weight gain. Importantly, the coefficient for the effect of BMI at the beginning of treatment on BMI at the end of treatment is not really of interest in such a model (and neither are concerns about multicollinearity) as BMI at the beginning of treatment *has to be* included in the model to answer the question whether weight suppression predicts weight change.

The same issue applies when regressing BMI at the end of treatment on BMI at the beginning of treatment only. In a simple linear, ordinary-least-squares regression model—that is, a model that only includes one independent variable—the coefficient for the relationship between the independent variable (e.g., BMI at admission) and the dependent variable (e.g., BMI at discharge) does not include any information about changes over time but merely quantifies the between-persons relationship between the two variables. In fact, the standardized regression coefficient in such a model is equal to Pearson's correlation coefficient (Darlington & Hayes, 2017, p. 31). Thus, a positive and statistically significant regression coefficient in a model that includes BMI at admission as independent variable and BMI at discharge as dependent variable indicates that the rank-ordering of persons according to their BMI stays quite stable from admission to discharge: a person that has a higher BMI than another person at admission is likely to have a higher BMI at discharge than this person at discharge as well.

Unlike the weight suppression example above, the baseline values that one should control for to examine changes over time are already included in this model as the sole independent variable. Now one possibility to examine whether BMI at the beginning of treatment predicts weight change would be to construct a difference score (e.g., by subtracting BMI at admission from BMI at discharge) and then regress this BMI change on BMI at the beginning of treatment. Doing so will likely result in a negative coefficient for the effect of BMI at admission on BMI change, which is determined by the correlation between and the variance of the two measurements (Clifton & Clifton, 2019). That is, there will always be a correlation between the change score and the baseline values, regardless of any treatment effects (Clifton & Clifton, 2019).

The aim of this study was to demonstrate these relationships empirically by analyzing data from a large sample of persons with AN who received inpatient treatment. We then discuss what these relationships actually represent and how they should be interpreted.

Method

Sample

Data of 4863 persons with AN (ICD–10 code F50.0) who received inpatient treatment at the Schoen Clinic Roseneck (Prien am Chiemsee, Germany) between 2015 and 2024 were analyzed. Sample characteristics are displayed in Table 1. At the hospital, data from the routine diagnostic assessments (e.g., age, sex, diagnoses, BMI) are automatically transferred to a database from which they could be exported without any identifying information (e.g., name, date of birth, place of residence) by authorized employees. Thus, accessing individual patient charts is not necessary. According to the guidelines by the ethics committee of the LMU Munich, retrospective studies conducted on already available, anonymized data are exempt from requiring ethics approval.

The treatment at the hospital adheres to the German S3-guidelines for the treatment of AN (AWMF, 2020) in terms of admission criteria, treatment elements, and therapy goals. Thus, patients received a cognitive-behavioral therapy-oriented, multimodal AN treatment that included several treatment elements such as individual psychotherapy sessions, group therapy sessions, exercise therapy, meal preparation classes, body image exposure, nutrition counseling, and food intake protocols as well as clinical management of medical complications. The treatment includes a high-calorie refeeding schedule (starting on the first day of treatment) that aims at a weight gain of 0.7–1.0 kg per week for all underweight AN patients. This schedule includes three meals per day, each having approximately 700 kcal and, thus, totaling to a daily caloric intake of approximately 2100 kcal. Meals are supervised by a staff member (nurse, psychotherapist, or physician) in earlier treatment stages. The schedule is individually tailored if patients do not finish their meals or do not show the expected weight gain by increasing portion size, adding snacks between meals, or offering sip feeds. As normalization of eating behavior is one of the therapeutic goals, patients do not receive nasogastric feeding. Patients can choose between vegetarian and non-vegetarian menus; vegan menus are not offered.

Data analyses

Data were analyzed with R version 4.3.2 in RStudio version 2023.12.1. Note that it is generally recommended to use age- and sex-adjusted BMI for children and adolescents because of growth-related changes in body composition (Cole et al., 2000). However, BMI-SDS (obtained with the R package *childsds* using German reference data) were highly correlated with BMI in the current sample (r = 0.85), which is why we only analyzed BMI to avoid redundancy. Changes in BMI from admission to discharge were tested with a paired samples t-test. Relationships of study variables with BMI at admission and BMI change (BMI at admission subtracted from BMI at discharge) were tested with Pearson's correlation coefficients and point-biserial correlation coefficients. To demonstrate that the standardized coefficient in a linear, ordinary-least-squares regression model is equivalent to Pearson's r when there is only one independent variable, BMI at discharge and BMI change were regressed on BMI at admission in two separate models. To further visualize BMI change as a function of BMI at admission, we arbitrarily created a group of persons with a BMI ≤15 kg/m² (n = 2361) and a group of persons with a BMI >15 kg/m² (n = 2502) and formally tested differential changes in BMI from admission to discharge as a function of these groups with an analysis of variance for repeated measures. The data and code with which the results reported here can be reproduced can be accessed at https://osf.io/9v3fk.

Results

BMI increased from admission to discharge with a large effect size ($t_{(4862)} = 93.2$, $p < .001$, $d = 1.3$; Table 1). BMI at admission positively correlated with BMI at discharge with a large effect size (Figure 1A) and negatively correlated with BMI change with a medium effect size (Figure 1B; Table 1). As outlined in the introduction section, the correlation coefficients (Figure 1; Table 1) are equal to the standardized coefficients when regressing BMI at discharge on BMI at admission ($\beta = 0.55$, $p < .001$) and when regressing BMI change on BMI at admission ($\beta = -0.39$, $p < .001$). The effect of BMI at admission on BMI change was still negative and significant ($\beta = -0.27$, $p < .001$) when controlling for age, sex, length of stay, and comorbid mental disorders.

The interaction effect groups × time was significant ($F_{(1,4861)} = 569.3$, $p < .001$, $\eta^2_G = 0.04$), indicating that BMI change from admission to discharge differed in the two groups. Figure 1C visualizes the effect of BMI at admission on BMI change by displaying BMI at admission and discharge in persons with a BMI at admission ≤15 kg/m² and >15 kg/m². As this depiction is merely a different way of displaying the effect presented in Figure 1B, persons with a lower BMI at admission showed a steeper slope (i.e., larger weight gain from admission to discharge) than persons with a higher BMI at admission. Despite this larger weight gain, however, BMI at discharge was still lower than in persons with a higher BMI at admission (Figure 1C).

Discussion

The current study demonstrates that the statement of higher BMI at the beginning of treatment being a predictor of better treatment outcome in persons with AN is only partially true. BMI at admission correlates positively with BMI at discharge, indicating that a person who has a higher BMI than another person at admission also tends to have a higher BMI than this person at discharge. That is, regressing BMI at the end of treatment on BMI at the beginning of treatment does not answer the question whether a person with a low or high body weight at admission responds better or worse to the treatment. Instead, the positive coefficient rather indicates that interindividual differences in body weight remain quite stable across different time points.

When examining weight change, lower BMI at admission relates to larger weight gain and, vice versa, higher BMI at admission relates to smaller weight gain during inpatient treatment in persons with AN. Despite this larger weight gain, persons with lower BMI at admission do not tend to reach comparable BMI levels at discharge as those with higher BMI at admission. Importantly, this relationship is far from being groundbreaking as there is always a correlation between change and baseline scores in treatment studies, regardless of any treatment effect (Clifton & Clifton, 2019). This correlation depends on the correlation between the two measurements and their variances as is described in formular #9 in the article by Clifton and Clifton (2019):

$$corr(Y - X, X) = \frac{\rho\sigma_x\sigma_y - \sigma_x^2}{\sigma_x\sqrt{(\sigma_y^2 - 2\rho\sigma_x\sigma_y + \sigma_y^2)}} = \frac{\rho\sigma_y - \sigma_x}{\sqrt{(\sigma_y^2 - 2\rho\sigma_x\sigma_y + \sigma_y^2)}}$$

In the current example, *X* would be BMI at admission, *Y* would be BMI at discharge, $\sigma^2{}_X$ and $\sigma^2{}_Y$ are their variances, and ρ is the correlation between *X* and *Y*. Entering the correlation between BMI at admission and BMI at discharge (.55) for ρ, the standard deviation of BMI at admission (1.9) for $\sigma^2{}_X$, and the standard deviation of BMI at discharge (2.1) for $\sigma^2{}_Y$ in this formular yields a correlation of .39, that is, the correlation coefficient for the relationship between BMI at admission and BMI change (Table 1).

There are numerous factors that might influence this relationship. Statistically, difference scores (here: BMI change) tend to be negatively correlated with the initial state (here: BMI at admission) due to regression to the mean (Hayes & Rockwood, 2017). That is, extreme values usually tend to get more moderate over time (i.e., extremely high values tend to decrease and extremely low values tend to increase). Correspondingly, the current findings mirror effects observed in the treatment of obesity: persons with a higher body weight at the beginning of treatment tend to lose more weight than those with a lower body weight (but despite this larger weight loss, those starting with a higher weight still have a higher weight than those starting with a lower weight at the end of treatment; Christiansen et al., 2007). Biologically, larger weight gain in those with lower BMI may be due to lower resting metabolic rate at the beginning of treatment. Psychologically, many patients accept that they have to gain weight during treatment but refuse to exceed certain self-imposed thresholds (e.g., 50 kg), which are reached faster by those who start with higher BMI at admission. In line with all three of these factors, rates of weight gain usually level off during the course of treatment (Meule et al., 2022). In either case, an incorrect interpretation would be that the treatment is more effective for patients with a lower body weight at admission as examining the correlation between BMI at admission and BMI change cannot answer this question.

Interpretation of the current findings is, of course, limited to inpatients with AN in Germany and may not translate to other treatment forms (e.g., day-patient or outpatient treatment) or to countries with different healthcare systems. Moreover, the current analyses were restricted to body weight for the sake of brevity and clarity, but treatment outcome should, of course, not only be evaluated using body weight but also by considering other eating disorder symptomatology (e.g., restrictive eating patterns, excessive exercise, body image disturbance) and related psychopathology (e.g., depressive symptoms). However, as we clearly demonstrated, these findings are to be expected for any kind of such variables due to the statistical dependence between admission and change scores.

In conclusion, when considering body weight at the beginning of treatment as predictor of treatment outcome in persons with AN, this aim becomes complicated when the outcome variable is the same as the predictor variable (i.e., BMI). While a patient with a higher BMI than another patient at admission will likely have a higher BMI than that patient at discharge as well, this does not indicate that both persons responded differently to the treatment. Vice versa, the patient with a lower BMI at admission will likely gain more weight during treatment than the patient with a higher BMI at admission but this effect should not be interpreted as a better responding to treatment either.

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Table 1

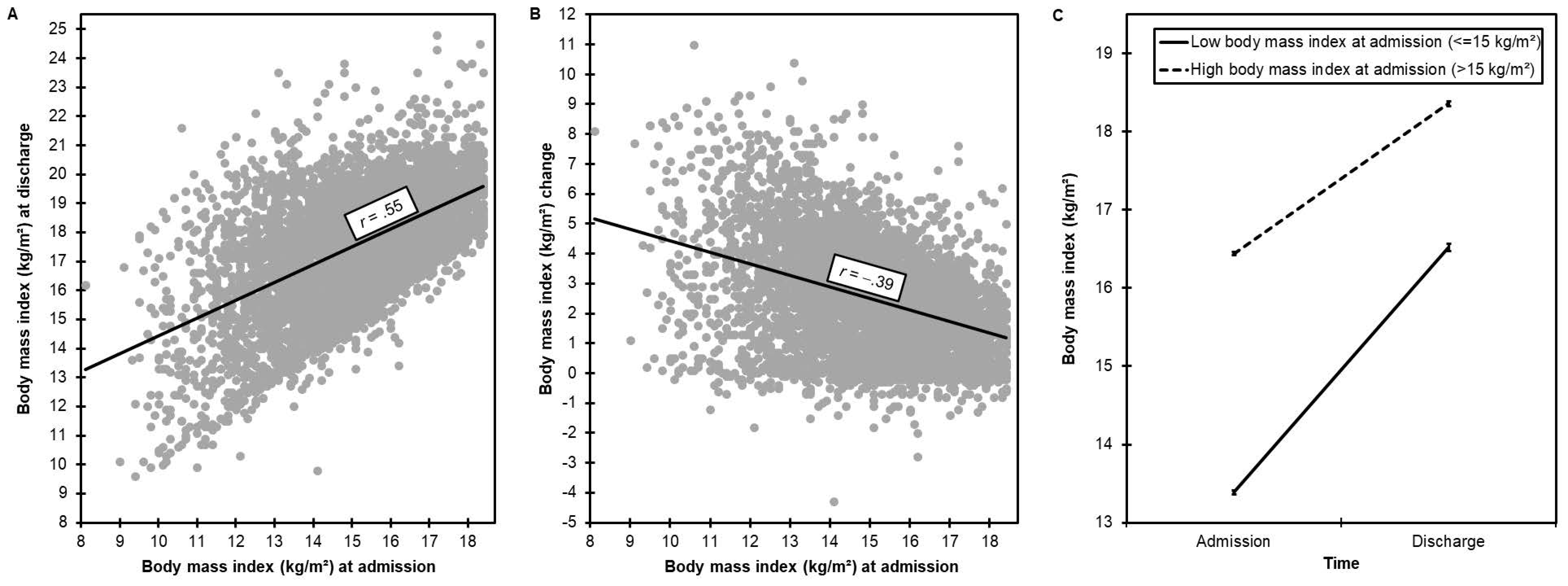
Descriptive statistics of study variables and correlations with body mass index (BMI) at admission and BMI change

N = 4863	Descriptive statistics	$r_{\text{BMI admission}}$	$r_{\text{BMI change}}$
BMI (kg/m²) at admission	M = 15.0 (SD = 1.9)	—	–.387 (p < .001)
BMI (kg/m²) at discharge	M = 17.5 (SD = 2.1)	.552 (p < .001)	.555 (p < .001)
BMI (kg/m²) change	M = 2.5 (SD = 1.9)	–.387 (p < .001)	—
Age (years)	M = 22.3 (SD = 9.8)	–.075 (p < .001)	–.004 (p = .788)
Sex (0 = female, 1 = male)	3.3% (n = 160)	.088 (p < .001)	–.034 (p = .018)
Length of stay (days)	M = 92.5 (SD = 55.4)	–.182 (p < .001)	.679 (p < .001)
Any comorbid mental disorders (0 = no, 1 = yes)	65.2% (n = 3170)	.068 (p < .001)	–.015 (p = .298)

Notes. r indicates Pearson's correlation coefficients when both variables are continuous and point-biserial correlation coefficients when one of the variables is dichotomous.

Figure caption

Figure 1. Panel A displays a scatterplot with linear trend line, visualizing the relationship between body mass index at admission and discharge. Panel B displays a scatterplot with linear trend line, visualizing the relationship between body mass index at admission and the difference score of body mass index at admission subtracted from body mass index at discharge. Panel C displays mean body mass index at admission and discharge as a function of persons with a body mass index ≤15 kg/m² and >15 kg/m² at admission. Error bars represent standard errors of the mean. Note that these analyses were based on arbitrarily categorizing the sample into these two groups, but this depiction only serves the purpose of visualizing the effect displayed in Panel B in a different way.



A
B
C
Body mass index (kg/m²) at discharge
Body mass index (kg/m²) at admission
r = .55
Body mass index (kg/m²) change
r = −.39
Low body mass index at admission (<=15 kg/m²)
High body mass index at admission (>15 kg/m²)
Body mass index (kg/m²)
Admission
Discharge
Time