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Physical Impairment and Access to Kidney Transplantation

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Abstract

Background: The Short Physical Performance Battery (SPPB) test is an objective measurement of lower extremity function (walk speed, balance, chair stands). SPPB impairment is associated with longer length of stay and increased mortality in kidney transplant (KT) recipients. Furthermore, the SPPB test may represent an objective quantification of the ‘foot of the bed test’ utilized by clinicians; therefore, impairment may translate with decreased access to KT.

Methods: We studied 3,255 participants (2009–2018) at two KT centers. SPPB impairment was defined as a score of ≤ 10 . We estimated time to listing, waitlist mortality, and transplant rate by SPPB impairment status using Cox proportional hazards, competing risks, and Poisson regression.

Results: The mean age was 54 years (SD=14; range 18–89) and 54% had SPPB impairment. Impaired participants were less likely to be listed for KT (adjusted hazard ratio:0.70, 95%CI:0.64–0.77, $p<0.001$). Also, once listed, impaired candidates had a 1.6-fold increased risk of waitlist mortality (adjusted subhazard ratio:1.56, 95%CI:1.18–2.06, $p=0.002$). Furthermore, impaired candidates were transplanted 16% less frequently (adjusted incidence rate ratio:0.84, 95%CI:0.73–0.98, $p=0.02$).

Conclusions: SPPB impairment was highly prevalent in KT candidates. Impaired candidates had decreased chance of listing, increased risk of waitlist mortality, and decreased rate of KT. Identification of robust KT candidates and improvement in lower extremity function are potential ways to improve survival on the waitlist and access to KT.

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AUTHOR CONTRIBUTIONS

CEH, DA, NMC, NMD, DLS, and MMD contributed to the conception and design; CEH, DA, LL, JL, NMD, SPN, DCB, DLS, and MMD contributed to the acquisition of data or analysis and interpretation of the data; CEH, DA, NMC, LL, JL, NMD, SPN, DCB, DLS, and MMD contributed to drafting the article or revising it critically for important intellectual content; CEH, DA, NMC, LL, JL, NMD, SPN, DCB, DLS, and MMD approved the final version to be published and are accountable for all aspects of the work.

DISCLOSURES

Authors have no conflict of interest to report as described by *Transplantation*.

INTRODUCTION

The Short Physical Performance Battery (SPPB) test is an objective measurement of lower extremity function combining walk speed, balance, and chair stands.¹ It was first identified and validated in community-dwelling older adults,¹ and SPPB impairment is associated with mortality, lower quality of life, and functional decline.^{2–5} In end-stage renal disease (ESRD) patients, SPPB impairment is highly prevalent,^{2,4,6} declines over time on hemodialysis, and is predictive of falls.⁴ Furthermore, nearly half of kidney transplant (KT) recipients have SPPB impairment.^{7,8} It is associated with a longer length of stay after KT,⁷ 2.3-fold increased risk of mortality in KT recipients,⁸ and improved risk prediction for post-KT mortality versus the standard registry model (c-statistic: 0.76 vs. 0.69).^{8,9} Despite poor outcomes for impaired ESRD patients and KT recipients, the associations between SPPB impairment and access to KT are unknown. The SPPB test may represent an objective quantification of the ‘eyeball test’ or ‘foot of the bed test’ commonly used by clinicians^{10–12}; therefore, less objective measurements of impairment like these clinical quantifications may result in decreased access to KT. Furthermore, characterization of the relationship of SPPB impairment and listing for KT as well as transplantation may help identify a population that could be targeted with interventions to improve access to KT.

Clinicians have difficulty correctly identifying frail patients due to the subjective nature of this assessment,¹³ which leads to poor risk stratification for KT candidates. The Fried physical frailty phenotype, commonly used in research studies of transplant populations,^{14–19} includes patient-reported energy levels, unintentional weight loss, and physical activity,²⁰ whereas the SPPB test contains only objective measures.¹ SPPB impairment captures a vulnerability that is distinct from frailty in this population and identify different groups of vulnerable KT recipients.⁸ While both include measures of walk speed, the SPPB is a measure of lower extremity function while frailty measures a more global measure of physiologic reserve. Furthermore, the SPPB test is easily administered, completely objective, and could also be used for waitlist mortality risk stratification in KT candidates. This is increasingly relevant as an increased number of older adults undergo KT,²¹ and older KT recipients are more likely to have lower extremity impairment.² Thus, identification of robust older KT candidates and improvement in lower extremity function while awaiting KT are important for improved waitlist survival and likely improved post-KT outcomes. Notably, lower extremity impairment is a potentially modifiable candidate characteristic,²² unlike age,^{23,24} sex,^{25–27} or race,²⁸ which could be improved while on dialysis and prior to KT.²⁹

To test whether SPPB impairment is associated with access to KT and waitlist outcomes in ESRD patients who are referred for KT evaluation, we conducted a two-center prospective cohort of 3,255 participants evaluated for KT and quantified the impact of SPPB impairment on listing, waitlist mortality, and transplant rates.

METHODS

Study design

This was a prospective, longitudinal cohort of 3,255 participants who were 18 years of age or older and evaluated for transplantation at the Johns Hopkins Hospital, Baltimore, Maryland from November 2009 to March 2018 (n=2,977) and the University of Michigan, Ann Arbor, Michigan, from January 2015 to October 2016 (n=278). In this study, the SPPB test was administered at time of KT evaluation, as described below. Recipient factors (age, sex, race, body mass index [BMI], blood type, time on dialysis and Charlson comorbidity index [CCI]) were also assessed at this time or abstracted from the transplant evaluation medical record. The Johns Hopkins Institutional Review Board and the University of Michigan Institutional Review Board approved the study. The humans in this study were treated in a manner in accordance with the Declaration of Helsinki and the Declaration of Istanbul.

Short Physical Performance Battery (SPPB) test

The SPPB was measured at the time of evaluation for KT by trained research assistants and consists of three components: standing balance (ability to stand with the feet together in the side-by-side, semi-, and tandem positions), walking speed (time to walk an 8-foot course) and repeated chair stands (time to rise from a chair and return to the seated positions 5 times).¹ Each of the three components had a score ranging from 0 to 4, for a cumulative composite score ranging from 0 to 12. SPPB impairment was defined as a score of ≤ 10 , a previously established cutoff in organ transplantation.^{3,7,8} The results of SPPB testing were not available to the clinicians at time of listing and were collected for research purposes.

Frailty

We studied the physical frailty phenotype as defined²⁰ in older adults as well as in ESKD and kidney transplant populations.^{14,15,18,19,30–41} The Fried physical frailty phenotype was based on 5 components: shrinking (self-report of unintentional weight loss of more than 10 pounds in the past year based on dry weight); weakness (grip-strength below an established cutoff based on gender and BMI); exhaustion (self-report); low activity (Kcals/week below an established cutoff); and slowed walking speed (walking time of 15 feet below an established cutoff by gender and height).²⁰ Each of the 5 components was scored as 0 or 1 representing the absence or presence of that component. The aggregate frailty score was calculated as the sum of the component scores (range 0–5); frailty was defined as a score of ≥ 3 . The physicians were not aware of the frailty assessment results at time of evaluation, and these measurements were collected for research purposes.

Time to KT listing

Time to listing among participants evaluated for KT was defined as the time from interview date to first active date on the waitlist. The Kaplan Meier method was used to estimate the cumulative incidence of KT listing at 6 months, 1 year and 3 years and to create unadjusted cumulative incidence curves of KT listing by SPPB impairment status. Cox proportional hazards models were used to estimate the chance of KT listing by SPPB impairment status,

adjusting for age, sex, and race. Proportional hazards assumption was assessed by visual inspection of complementary log-log plots. To investigate whether the association of SPPB impairment and time to KT listing differed by age (older [age ≥65] vs. younger [age 18–64]), sex, race, or comorbidity burden (Charlson comorbidity index [CCI] <2 and CCI ≥2),¹⁶ we explored an interaction between each candidate characteristic and SPPB impairment, separately using a Wald test.

Waitlist mortality

The risk of waitlist mortality among participants listed for KT was estimated at 6 months, 1 year, 3 years and 5 years using a competing risk model by SPPB impairment status with listing date as the time origin. A competing risk model was used to create unadjusted cumulative incidence curves of waitlist by SPPB impairment status, and KT was treated as a competing risk. Subhazard ratios (SHR) of waitlist mortality were obtained using the Fine and Gray competing risk regression model,⁴² adjusting for age, sex, race, BMI, blood type, cause of ESRD, and CCI. To investigate whether the association of waitlist mortality and SPPB impairment differed by age (older [age ≥65] vs. younger [age 18–64]), sex, race, or comorbidity burden (CCI <2 and CCI ≥2), we explored an interaction between each candidate characteristic and SPPB impairment, separately using a Wald test. To explore the predictive value by the addition of Fried frailty phenotype and/or SPPB impairment to the waitlist mortality model, we calculated the c statistic for discrimination comparing the following models: none (reference; no addition of frailty or SPPB impairment), frailty, SPPB impairment, and SPPB impairment+frailty. Additionally, we compared the c statistic for discrimination between SPPB impairment and SPPB impairment+frailty models.

Transplant rate

The KT rate among participants listed for KT was estimated at 6 months, 1 year, 3 years and 5 years using a competing risk model by SPPB impairment status with listing date as the time origin. A competing risk model was also used to create unadjusted cumulative incidence curves of KT by impairment status, and waitlist mortality was treated as a competing risk. Incidence rate ratios (IRR) of KT were obtained by Poisson regression and person-time was calculated from listing date to KT date, mortality, or censoring on March 1, 2018. This model was adjusted for age, sex, race, BMI, blood type, cause of ESRD, and CCI. To investigate whether the association of transplant rate and SPPB impairment differed by age (older [age ≥65] vs. younger [age 18–64]), sex, race, or comorbidity burden (CCI <2 and CCI ≥2), we explored an interaction between each candidate characteristic and SPPB impairment, separately using a Wald test. To explore the predictive value by the addition of Fried frailty phenotype and/or SPPB impairment to the transplant rate model, we calculated the c statistic for discrimination comparing the following models: none (reference; no addition of frailty or SPPB), frailty, SPPB, and SPPB+frailty. Additionally, we compared the c statistic for discrimination between SPPB and SPPB+frailty models.

Statistical analyses

The distribution of variables was presented as mean (standard deviation [SD]) for continuous variables and frequency (percentage) for categorical variables. Comparisons of candidate characteristics were performed using t-tests for continuous variables and chi-squared tests

for categorical variables. All statistical analyses were performed using Stata version 15 (StataCorp, College Station, TX). Two-sided p-values < 0.05 were considered statistically significant.

Sensitivity analysis

Among 1,906 participants being evaluated for KT with self-reported comorbidity burden measured, we used Cox proportional hazards models to estimate the chance of KT listing by SPPB impairment status, adjusting for age, sex, race, and CCI. Proportional hazards assumption was confirmed by visual inspection of complementary log-log plots.

RESULTS

Study population: Participants evaluated for KT

Among 3,255 participants being evaluated for KT, the mean age was 54 years (SD= 14; range 18–89), 24.1% were older (age ≥ 65), 40% were female, and 45% were African American. Of participants being evaluated for KT, 1,760 (54.1%) had SPPB impairment (Table 1). The median (interquartile range) SPPB score was 10 (9–12). Impaired participants were more likely to be older (57.4 vs. 49.9 years, $p<0.001$), African American (47.4% vs. 41.5%, $p=0.01$), a current smoker (13.1 vs. 10.1, $p=0.01$), and had a higher CCI (2.1 vs. 1.3, $p<0.001$) compared to nonimpaired participants (Table 1).

Among 3,143 participants being evaluated for KT with Fried frailty and SPPB measured, 1,227 (39.0%) had only SPPB impairment, 157 (5.0%) were only frail, and 1,322 (42.0%) had neither SPPB impairment or were frail; only 437 (11.0%) had both SPPB impairment and were frail.

SPPB impairment and time to KT listing

Impaired participants were less likely to be listed compared to nonimpaired participants (log rank $p<0.001$) (Figure 1). Cumulative incidence of KT listing, in impaired versus nonimpaired KT participants, was 45.8% vs. 57.4% at 6 months, 54.2% vs. 65.7% at 1 year, and 58.5% vs. 71.2% at 3 years (Table 1). After adjustment, impaired participants were at a 30% decreased chance of listing compared to nonimpaired participants (adjusted hazard ratio [aHR]: 0.70, 95%CI: 0.64–0.77, $p<0.001$) (Table 2).

In a univariable model, the association between time to listing and SPPB impairment varied by candidate age (interaction $p=0.04$). After adjustment, this association remained (p interaction=0.04). Impaired older participants were 41% less likely to be listed than nonimpaired older participants (aHR: 0.59, 95%CI: 0.49–0.72, $p<0.001$); however, impaired younger participants were only 26% less likely to be listed than nonimpaired younger participants (aHR: 0.74, 95%CI: 0.67–0.82, $p<0.001$).

In univariable models, the association between listing and SPPB impairment did not vary by candidate sex (p interaction=0.1) or race (p interaction=0.8). Similarly, in multivariable models, the association between time to listing and SPPB impairment did not vary by participant sex (interaction $p=0.2$), race (interaction $p=0.9$), or comorbidity burden (interaction $p=0.7$).

Study population: Participants listed for KT

Among 3,255 participants evaluated for KT, 1,951 were listed for KT during the study period. The average age of among participants listed for KT was 54 years (SD=14, range 18–89) and 22.7% were older (age ≥ 65). 942 (48.3%) participants listed for KT were impaired. The median (interquartile range) SPPB score was 11 (9–12). Impaired participants listed for KT were more likely to be older (56.9 vs. 49.9 years, $p<0.001$). Impaired participants listed for KT were more likely to have a higher CCI score (2.3 vs. 1.4, $p<0.001$). Impaired candidates were more likely to have diabetes (25.5% vs. 14.2%, $p<0.001$) and hypertension (31.3% vs. 29.0%, $p<0.001$) and less likely to have glomerular disease (16.7% vs. 27.1%, $p<0.001$) as the cause of renal failure. Impaired and nonimpaired candidates had a similar distribution of blood types ($p=0.6$).

SPPB impairment and waitlist mortality

Waitlist mortality was higher in impaired participants listed for KT compared to nonimpaired KT participants (log rank $p<0.001$) (Figure 2). The cumulative incidence of waitlist mortality for impaired versus nonimpaired participants was 1.5% vs. 0.7% at 6 months, 3.7% vs. 1.2% at 1 year, 20.9% vs. 10.3% at 3 years, and 42.4% vs. 30.2% at 5 years after listing (Table 1). After adjustment for participant demographic and health factors, impaired participants had nearly 1.6-fold higher risk of waitlist mortality (adjusted subhazard ratio [aSHR]: 1.56, 95%CI: 1.18–2.06, $p=0.002$) compared to nonimpaired participants (Table 1).

In univariable models, the association between waitlist mortality and SPPB impairment did not vary by candidate age (p interaction=0.6), sex (p interaction=0.96), or race (p interaction=0.8). Similarly, in multivariable models, the association between waitlist mortality and SPPB impairment did not vary by participant age (interaction $p=0.8$), sex (interaction $p=0.5$), race (p interaction=0.9), or comorbidity burden (interaction $p=0.4$).

Compared to the waitlist mortality model (without the addition of frailty or SPPB impairment), the addition of frailty, SPPB, or SPPB +frailty improved the discrimination (c statistic frailty: 0.68, $p<0.001$; c statistic SPPB: 0.68, $p<0.001$; c statistic SPPB+frailty: 0.68, $p<0.001$) (Table 3). Including both SPPB+frailty did not improve the discrimination better than just SPPB alone ($p=0.9$).

SPPB impairment and transplant rate

The cumulative incidence of KT was lower among impaired participants listed for KT than nonimpaired (log rank $p<0.001$) (Figure 3). The cumulative incidence of KT for impaired versus nonimpaired participants was 12.5% vs. 14.9% at 6 months, 20.9% vs. 27.1% at 1 year, 41.4% vs. 58.2% at 3 years, and 54.7% vs. 72.5% at 5 years (Table 1). After adjustment for participant demographic and health factors, impaired participants were 16% less likely to undergo KT compared to nonimpaired (adjusted incidence rate ratio [aIRR]: 0.84, 95%CI: 0.73–0.98, $p=0.02$) (Table 1).

In univariable models, the association between transplant rate and SPPB impairment did not vary by candidate age (p interaction=0.3), sex (p interaction=0.1), or race (p

interaction=0.6). Similarly in multivariable models, the association between transplant rate and SPPB impairment did not vary by participant age (interaction $p=0.8$), sex (interaction $p=0.5$), race (p interaction=0.4), or comorbidity burden (interaction $p=0.8$).

Compared to the transplant rate model (without the addition of frailty or SPPB impairment), the addition of frailty, SPPB, or SPPB +frailty improved the discrimination (c statistic frailty: 0.65, $p<0.001$; c statistic SPPB: 0.66, $p<0.001$; c statistic SPPB+frailty: 0.66, $p<0.001$) (Table 3). Including both SPPB+frailty did not improve the discrimination better than just SPPB alone ($p=0.5$).

Sensitivity analysis

Among 1,906 participants being evaluated for KT with comorbidity burden measured, participants with SPPB impairment were 22% less likely to be listed (aHR: 0.78, 95% CI: 0.71–0.86, $p<0.001$) than those without SPPB impairment.

DISCUSSION

In this two-center prospective cohort of SPPB impairment including 3,255 participants evaluated for KT, 54.3% had SPPB impairment, and impaired participants were more likely to be older ($p<0.001$) and have a higher comorbidity burden ($p<0.001$). Notably, 39.0% of participants had only SPPB impairment, 5.0% were only frail, and 42.0% had neither SPPB impairment or were frail; only 11.0% had both SPPB impairment and were frail. Impaired participants evaluated for KT were 30% less likely to be listed for KT ($p<0.001$), with a stronger association in older participants (interaction $p=0.04$). Additionally, impaired participants listed for KT had a 1.6-fold higher risk of waitlist mortality ($p=0.002$) and were 14% less likely to undergo KT ($p=0.02$) compared to nonimpaired participants listed for KT. Also, the addition of the SPPB test to waitlist mortality and transplant rate models improved the discrimination of the models, and the addition of frailty to SPPB did not improve discrimination over the addition of SPPB alone.

Our findings of a lower chance of KT listing in impaired participants, with a stronger association in older participants, are important to consider with respect to previous studies that show as patient age increases, the odds and relative rate of KT listing after evaluation for older candidates decrease.^{23,28} Our finding that older participants were more likely to have SPPB impairment is consistent with higher prevalence of SPPB impairment in older dialysis patients²; however, we extend these findings to show an association with deceased listing for KT that is more strongly associated in older participants. This suggests that providers may be more willing to overlook impairment in the components of the Short Physical Performance Battery (SPPB) more when the patient is younger and may not weigh these objective measures in the same as in older adults.

Additionally, our finding of increased waitlist mortality associated with SPPB impairment is similar to previous work by our group that assessed the association of Fried frailty and waitlist mortality in KT candidates.⁴⁰ This is not surprising given the Fried frailty phenotype and SPPB both measure walking speed and other components that estimate physical muscular capacity (chair stands, balance vs. grip strength). However, SPPB may better

capture additional risk domains over Fried frailty, as demonstrated by the association of SPPB and increased risk of post-KT mortality, independent of Fried frailty.⁸ We found that 39% of participants had SPPB impairment and were not frail, while only 11% of participants had SPPB impairment and were frail, suggesting these are distinct concepts. Additionally, we found that the addition of SPPB to waitlist mortality and transplant rate models improved the discrimination, and that SPPB and frailty did not significantly improve the discrimination over SPPB alone. Measurement of SPPB over Fried frailty at evaluation identifies more vulnerable patients (54% vs. 18%),⁴⁰ and those with lower extremity impairment as measured by the SPPB may be a more relevant population for prehabilitation.⁴³

Our finding of lower KT rate in impaired versus nonimpaired candidates is important to consider in conjunction with previous studies that demonstrated older candidates are less likely to undergo KT than younger candidates.^{23,28} We further quantified the association of SPPB impairment and transplant rate in KT candidates, and our findings demonstrate that SPPB impairment status leads to a lower incidence of KT, regardless of age. Thus, given that SPPB impairment is more prevalent in older candidates, it may be one mechanism contributing to the decreased KT rates in older candidates. These findings may represent surgeons' hesitation to accept organ offers, waiting for better subsequent offer, for impaired KT candidates. This behavior would be supported by the fact that KT recipients with SPPB impairment have longer length of stay⁴⁴ and increased risk of mortality after KT.⁸

Strengths of this study include a large sample size cohort from two hospitals, prospective study design, and the novel measurement of the SPPB test, not currently captured in large registries. One limitation to our study was selection bias based on who is referred for KT evaluation from the community, but there is no way to administer the SPPB test in patients who are not referred for evaluation. In other words, if SPPB impaired participants were less likely to be referred for KT evaluation, we may see conservative estimates of the association between SPPB impairment and access to KT in our analyses. Another limitation was provider bias related to listing practices; for example, the impact of SPPB impairment associated with listing is stronger in older participants than in younger participants, but we were unable to quantify potential bias for listing decisions.

In conclusion, SPPB impairment is associated with decreased listing, higher waitlist mortality, and lower incidence of KT. The SPPB test is a completely objective test, is easily measured in clinical practice at evaluation, and could be used to identify patients who are at high risk for poor outcomes at evaluation and while awaiting transplant. Importantly, SPPB impairment, a measure of lower extremity function, is a potentially modifiable risk factor,²² so optimization, for example through prehabilitation,⁴³ while on dialysis could likely improve outcomes in this vulnerable group and should be considered during the listing meeting in conjunction with a patient's age, comorbidities, and other considerations.

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Abbreviations

aHR	adjusted hazard ratio
aIRR	adjusted incidence rate ratio
aSHR	adjusted subhazard ratio
BMI	body mass index
CCI	Charlson comorbidity index
ESRD	end-stage renal disease
KT	kidney transplantation
SD	standard deviation
SPPB	short physical performance battery

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Figure 1. Cumulative incidence of listing for kidney transplantation (KT) in evaluation patients (n=3,255) evaluated patients by SPPB impairment status (≥ 10).

Figure 2. Cumulative incidence of waitlist mortality in 1,951 waitlisted patients by SPPB impairment status ($n = 10$).

Figure 3. Cumulative incidence of kidney transplantation (KT) in n=1,951 waitlisted patients by SPPB impairment status ($n=10$).

Table 1.

Characteristics of 3,255 kidney transplant (KT) evaluation candidates by SPPB impairment status (= 10).

	No SPPB impairment (n = 1,495)	SPPB impairment (n = 1,760)	p value
Age, years	49.9 (14.1)	57.4 (12.2)	<0.001
Female, %	39.3	41.5	0.19
Ethnicity, %			0.01
African-American	41.5	47.4	
Non African American	58.6	52.6	
Charlson comorbidity index	1.3 (1.9)	2.1 (2.5)	<0.001
Current smoker, %	10.1	13.1	0.01
Ever smoker, %	28.1	38.8	<0.001
Time on dialysis, years	1.5 (2.8)	1.6 (3.2)	0.55
Hemodialysis, %	49.7	58.9	<0.001
Preemptive transplant, %	36.9	30.9	<0.001

Table 2.

Cumulative incidence (%) of listing, waitlist mortality, and kidney transplantation (KT). Cox proportional hazards were adjusted for age, sex, race and Charlson comorbidity index (CCI) for chance of KT listing. Competing risk models were used to quantify the risk of waitlist mortality by SPPB impairment status (10) in KT waitlist candidates. Transplant was treated as a competing risk, and models were adjusted for age, sex, race, BMI, cause of end-stage renal disease, blood type, and CCI. Poisson regression was used to calculate the incidence rate ratio of KT and adjusted for age, sex, race, BMI, cause of end-stage renal disease, blood type, and CCI.

		Cumulative incidence (%)						
Outcome by SPPB impairment	n	6 month	1 year	3 year	5 year			
Chance of listing						Adjusted HR	p value	
No SPPB impairment	1,495	57.4	65.7	71.2	72.6	REF		
SPPB impairment	1,760	45.8	54.2	58.5	59.4	0.64 ^{0.70} _{0.77}		<0.001
Risk of waitlist mortality						Adjusted SHR	p value	
No SPPB impairment	1,009	0.7	1.2	10.3	30.2	REF		
SPPB impairment	942	1.5	3.7	20.9	42.4	1.18 ^{1.56} _{2.06}		0.002
Chance of KT						Adjusted IRR	p value	
No SPPB impairment	1,009	14.9	27.1	58.2	72.5	REF		
SPPB impairment	942	12.5	20.9	41.4	54.7	0.73 ^{0.84} _{0.98}		0.02

HR= hazard ratio, SHR= subhazard ratio, IRR= incidence rate ratio

Table 3.

Predictive discrimination of waitlist (WL) mortality and transplant rate models. We tested the predictive discrimination of competing risks (WL mortality) and Poisson (transplant rate) models to quantify if addition of the Fried frailty phenotype, the short physical performance battery (SPPB), or both (Frailty +SPPB) improved the discrimination of the baseline adjusted model.

	WL Mortality		Transplant rate	
	C Statistic	p value	C Statistic	p value
None	0.64	REF	0.63	REF
Frailty	0.68	<0.001	0.65	0.001
SPPB	0.68	<0.001	0.66	<0.001
SPPB + Frailty	0.68	<0.001	0.66	<0.001

None refers to the c-statistic in the adjusted model without frailty or SPPB.