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Relationship between pre-transplant physical function and outcomes after kidney transplant

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Abstract

Background—Performance-based measures of physical function predict morbidity following non-transplant surgery. Study objectives were to determine whether physical function predicts outcomes after kidney transplant and assess how physical function changes post-transplant.

Methods—We conducted a prospective study involving living donor kidney transplants recipients at our center 5/2012 to 2/2014. Physical function was measured using the Short Physical Performance Battery (SPPB) (balance, chair stands, gait speed) and grip strength testing. Initial length of stay (LOS), 30-day rehospitalizations, allograft function and quality of life (QOL) were assessed.

Results—The majority of the 140 patients in our cohort had excellent pre-transplant physical function. In general, balance scores were more predictive of post-transplant outcomes than the SPPB. Decreased pre-transplant balance was independently associated with longer LOS and increased rehospitalizations but not with post-transplant QOL. 35% of patients experienced a clinically meaningful (≥ 1.0 m/s) improvement in gait speed four months post-transplant.

Conclusions—Decreased physical function may be associated with longer LOS and rehospitalizations following kidney transplant. Further studies are needed to confirm this association. The lack of relationship between pre-transplant gait speed and outcomes in our cohort may represent a ceiling effect. More comprehensive measures, including balance testing, may be required for risk stratification.

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AUTHOR CONTRIBUTIONS

All of the authors contributed substantially to the design and revision of the work, in addition to final approval of the manuscript. All authors agree to be accountable for the parts of the work he or she has done.

INTRODUCTION

Kidney transplant candidates are becoming older and more medically complex [1, 2]. Better objective methods of identifying candidates at high-risk of post-transplant morbidity are needed. Ideally, such tools would not only improve risk stratification but also lead to interventions that improve post-transplant outcomes. One type of testing that has been shown to predict adverse postoperative events in patients undergoing non-transplant surgery is performance-based physical function testing. These tests assess patient functional status and measure strength, mobility, flexibility and balance. Physical function testing has been associated with increased length of stay, rehospitalizations, wound infections, cardiovascular events and death, following cardiac, colorectal and oncologic surgery [3–5]. Importantly, interventions designed to improve physical function have been shown to result in better postoperative outcomes [6, 7]. Despite its utility in predicting and improving outcomes across surgical specialties, the relationship between performance-based measures of physical function and outcomes after kidney transplant has not been studied.

The goals of this exploratory study were to assess physical function before and after kidney transplant using performance-based measures of physical function. Specifically, the Short Physical Performance Battery (SPPB) was utilized. The SPPB combines results of balance, chair stand and gait speed testing. The SPPB is easy to perform and has been validated in geriatric populations where it has been shown to predict disability, hospitalizations and death [8–10]. When performed with grip strength testing, the SPPB provides a robust assessment of global physical function and can serve as a benchmark for future interventions [11, 12]. SPPB component scores can also be analyzed individually [13]. For example, balance scores have been associated with functional decline in the elderly [14] and are lower in kidney transplant candidates compared to patients with other comorbidities [15]. We also examined the relationship between pre-transplant physical function and post-transplant outcomes, including initial hospital length of stay following transplant surgery, rehospitalizations, quality of life, new onset diabetes mellitus and renal allograft function.

MATERIALS AND METHODS

Patient population

We conducted a prospective observational study involving consenting adult recipients of living donor kidney transplants performed at our institution between 5/15/2012 and 2/18/2014. Consecutive patients scheduled to undergo living donor kidney transplant were screened at their preoperative evaluation within the week prior to transplant surgery. Clinical information was abstracted from electronic databases. The study was approved by the Mayo Clinic Institutional Review Board. All patients provided written informed consent and were followed for 12-months post-transplant for the purposes of this study. According to standard protocol at our center, all patients were asked to return to transplant clinic 4- and 12-months after transplant for routine post-transplant follow-up.

Performance-based physical function testing

Enrolled patients underwent pre-transplant SPPB and grip strength testing within the week prior to transplant surgery and during routine follow-up 4 months after kidney transplant. Testing was performed by a physical therapist (B.R.K.) using infrared photocells and load responsive switch mats to achieve a highly precise measurement [16]. SPPB methodology has been previously described; testing requires approximately 10 minutes to complete [17]. Briefly, the SPPB consists of three objective, performance-based measures of balance (tandem, semi-tandem and side-by-side stands), chair stands (time required to perform five chair stands) and gait speed (4-m walk). Depending on their performance, patients receive a score of 0 to 4 for each of the three components, with 0 indicating inability to complete the test and 4 indicating the best performance. Patients who can perform each of the three balance stands for 10 seconds receive a score of 4. When the SPPB has been completed, the component scores for balance, chair stands and gait speed are summed to provide a total SPPB score ranging from 0 to 12 [17]. In community-dwelling elderly adults, SPPB scores < 7 have been shown to predict disability and mortality [18]. In addition to SPPB testing, patients underwent grip strength testing in both hands using an electric hand dynamometer within the week prior to transplant surgery and 4 months after kidney transplant.

Outcomes and quality of life

Initial hospital length of stay following transplant surgery was assessed. Rehospitalization was defined as 1 hospital readmission within 30 days after discharge from the initial transplant hospitalization. Glomerular filtration rate (GFR) was measured using iothalamate clearance 12 months after transplant [19]. Fasting plasma glucose was measured at least monthly until 12-months post-transplant. According to previously published methodology, 12-month fasting plasma glucose was defined by averaging all fasting plasma glucoses obtained between post-transplant months 11 and 13 [20]. New-onset diabetes mellitus was defined as 12-month fasting plasma glucose $\geq$ 126 mg/dL. Patients with 12-month fasting plasma glucose < 126 mg/dL were also considered as having new-onset diabetes if they were using insulin or oral glucose-lowering agents.

Quality of life (QOL) was measured 12-months post-transplant using the Short Form 36 Health Survey (SF36) (version 1) [21]. SF36 forms were mailed to the patients. Patients who did not return the questionnaire by mail were subsequently contacted by the Mayo Clinic Survey Research Center and asked to answer the questions via phone. Members of the Survey Research Center were blinded to patient clinical data and results of performance-based physical function testing. SF36 scores range from 0 to 100 with higher scores indicating better quality of life. The SF36 assesses eight domains of health: physical functioning, role limitations due to physical health, bodily pain, general health, vitality, social functioning, role limitations due to emotional health and mental health. The SF36 generates two summary scores, the physical component summary (PCS) score which heavily weights measures of physical QOL, and the mental component summary (MCS) score which heavily weights measures of mental QOL. Standardized SF36 PCS and MCS scores are adjusted for age and gender using the mean and standard deviation of the general population of the United States. SF36 scores < 50 indicate below-average quality of life [22].

Statistical analysis

Data were expressed as means and standard deviation or median and range as appropriate. Continuous data were compared by Student's t-test and nonparametric tests (rank-sum test) for roughly normally distributed and heavily skewed data respectively. Multi-category data with most of the data in one category were analyzed as a dichotomous variable. Proportions were compared with the Chi-square test. Paired comparisons were done by student's t-test. The relationship between baseline variables including physical function variables, and endpoints of hospital length of stay (LOS) greater than 4 days, re-hospitalization within 30 days, and improvement in gait speed 4 months after transplant of 0.1 m/s were analyzed using logistic regression; endpoints of age and sex adjusted PCS at 12 months, age and sex adjusted MCS at 12 months, and mean 12 month iothalamate clearance corrected for body surface area were analyzed using linear regression. For the linear regression analysis, the dependent variable was log-transformed if it was too skewed. The relationship between baseline variables and balance <4 were analyzed using logistic regression. Regression diagnostics based on leverage, model residuals, change in the estimate of beta, and change in deviance were used to evaluate model fit for logistic regression models; similarly regression diagnostics based on leverage and model residuals were used to evaluate model fit for linear regression models. Stepwise logistic or linear regression with alpha equal to 0.05 to enter and leave was used for multivariate analysis, for dichotomous dependent and continuous variables, respectively, allowing all indicated univariate variables to compete. Profile likelihood was used for the 95% confidence intervals for odds ratios determined by logistic regression. Analyses were conducted with JMP, version 10, and SAS, version 9.3, SAS Institute, Inc.

RESULTS

Patient characteristics

A total of 151 patients were consecutively screened. Of those patients, 140 patients enrolled in the study and 11 patients (7.3%) chose not to participate. The baseline characteristics of the enrolled recipients are shown in Table 1. Among the enrolled cohort, 75 patients (53.6%) received induction with Thymoglobulin, 30 patients (21.4%) received basiliximab and 35 (25.0%) received alemtuzumab. Maintenance immunosuppression included mycophenolate mofetil and tacrolimus in all patients. Among the cohort, 37 patients (26.4%) received corticosteroid-free maintenance immunosuppression. One patient died 33 days post-transplant.

Pre-transplant physical function

Overall, 139 of the 140 enrolled patients completed pre-transplant SPPB testing. Results of pre-transplant physical function testing are summarized in Table 2. Among the cohort, 74.1% of patients (n=103 of 139) received a pre-transplant SPPB score equal to 12 suggesting excellent physical function. When SPPB component scores were analyzed, 82.0% of patients (n=114) had a pre-transplant balance score equal to 4, 79.1% (n=110) had a pre-transplant stand score equal to 4 and 95.0% (n=132) had a pre-transplant walk score equal to 4. Because so many of the multilevel SPPB scores were one level, SPPB scores were not analyzed as a continuous variable. Rather patients were categorized as achieving a

SPPB score < 12 or a SPPB score equal to 12. Likewise patients were categorized as achieving a balance score < 4 or equal to 4. Chair stand time and gait speed were analyzed as continuous variables.

Early post-transplant outcomes

Among our cohort of living donor kidney transplant recipients, the median initial hospital length of stay was 4 days (range 3–12 days) with 27.1% (n=38) staying longer than 4 days. Patients with pre-transplant balance scores < 4 were significantly more likely to experience a LOS > 4 days (44.0% vs 22.8%, p=0.03) and stayed one day longer in the hospital than patients with a score equal to 4 (5.44 ± 2.16 vs 4.39 ± 1.06 days, p=0.006) (Figure 1) but no relationship between mean LOS and SPPB score < 12, chair rise time or grip strength was identified. In general, pre-transplant balance scores < 4 were more predictive of post-transplant outcomes than SPPB scores < 12. On multivariate analysis using stepwise logistic regression with all the variables except re-transplant and with the additional variables of Thymoglobulin induction, steroid use, and grip strength (each hand) allowed to compete, a pre-transplant balance score < 4 was associated with more than a 3-fold higher rate of LOS > 4 days (OR 3.44, 95%CI 1.23–10.02, p=0.02). Additionally, Thymoglobulin induction and smoking history were associated with a hospital length of stay greater than 4 days (ORs of 9.6 and 2.9, respectively). Regression diagnostic tests suggest a good fit.

In our study, we observed a 30-day readmission rate of 15.7% (n=22). Reasons for rehospitalizations included the following: allograft dysfunction (8), lymphocele (2), DVT (2), cardiovascular disease (2), urine leak (1), wound infection (1), native nephrectomy (1), ileus (1), hypercalcemia (1), abdominal pain (1), arthralgias (1) and medication overdose (1). Patients with a pre-transplant balance score < 4 were significantly more likely to be rehospitalized within 30 days of transplant (40.0% vs 10.5%, p=0.0003) (Figure 1), but no relationship between rehospitalizations and grip strength or gait speed was observed. On univariate analysis, diabetes (OR 3.39, 95%CI 1.25–8.90, p=0.01), BMI (OR 1.17 per kg/m², 95%CI 1.06–1.30, p=0.002), SPPB < 12 (OR 3.68, 95%CI 1.42–9.59, p=0.007), balance score < 4 (OR 5.67, 95%CI 2.07–15.57, p=0.0007) and chair rise time (OR 1.14 per second, 95%CI 1.01–1.28, p=0.03) were associated with rehospitalization within 30 days. Two young patients (both age 28 years at transplant) were rehospitalized and were influential on the fit of the logistic model. Without these two patients, increasing age at transplant was associated with rehospitalization at 30 days (OR 1.55, 95%CI 1.08–2.38, p=0.03). On multivariate analysis using stepwise logistic regression and allowing the same variables to compete as for length of hospital stay, only pre-transplant BMI (OR 1.14 per kg/m², 95%CI 1.04–1.28, p=0.009) and balance score < 4 (OR 4.68, 95%CI 1.63–13.45, p=0.004) were associated with rehospitalization within 30 days. Even excluding the two young patients, age at transplant was not associated with rehospitalization in the multivariate analysis.

Relationship between balance and baseline variables

Patients with a balance score < 4 were more likely to be older, less likely to receive a preemptive transplant, and more likely to have a history of prior transplant, diabetes and coronary artery disease. They also had a higher BMI and were more likely to have an

elevated cardiac troponin T (cTNT) (Table 3). On multivariate analysis using stepwise logistic regression with all of the variables in Table 4 allowed to compete, a pre-transplant balance score < 4 was independently associated with increasing age (OR 2.13 per 10 year increase, 95%CI 1.34–3.76, $p=0.003$), diabetes (OR 4.24, 95%CI 1.42–12.99, $p=0.01$) and cTNT (OR 5.86, 95%CI 1.51–24.52 for cTNT 0.01–0.03 ng/mL compared to < 0.01 ng/mL, OR 8.64, 95%CI 2.11–39.13 for cTNT 0.04–0.1 ng/mL; OR 5.85, 95%CI 0.89–35.92 for cTNT >0.1 ng/mL, $p=0.01$) (Table 4). Regression diagnostic tests suggest a good fit.

Change in physical function post-transplant

Physical function testing was also performed 4 months after transplant (range 33–196 days). Among the cohort, 112 patients (80.0%) underwent post-transplant gait speed testing and 111 patients completed the entire SPPB post-transplant. The 28 patients who did not undergo post-transplant gait speed testing were more likely to be female (57.1% vs 42.9%, $p=0.02$) but did not have lower pre-transplant SPPB scores (11.3 ± 1.6 vs 11.0 ± 1.9 , $p=0.76$) or lower pre-transplant balance component scores (3.78 ± 0.57 vs 3.68 ± 0.75 , $p=0.55$). Following transplant, means of all measures of physical performance improved, except for the gait speed component score (Table 2). Overall, 20.7% of patients ($n=23$ of 111) had a post-transplant SPPB score < 12, and 12.6% of patients ($n=14$) had a post-transplant balance score < 4. Among the patients with pre-transplant SPPB scores < 12 or balance scores < 4, the majority experienced an improvement in their scores following transplant (Figure 2).

In addition to change in SPPB scores after transplant, we also examined change in gait speed after transplant. Among our cohort, 34.8% ($n=39$) of patients experienced an improvement in gait speed > 0.1 m/s, an increase consistent with clinically meaningful improvement [23, 24], while 17.8% ($n=20$) experienced a decrease in gait speed > 0.1 m/s. On multivariate analysis using stepwise regression and allowing the same variables as above to compete, male gender (OR 3.65, CI 1.43–10.42, $p=0.01$) was the only variable independently associated with > 0.1 m/s improvement in gait speed. In contrast, no relationship between clinically meaningful improvement in gait speed and recipient age, diabetes, maintenance steroid use or other measures of physical function was observed. Regression diagnostic tests suggest a good fit.

12-month post-transplant outcomes

Of the 139 surviving study patients, 108 patients (77.7%) completed the SF36 12-months after transplant. The 31 patients who did not complete the SF36 were younger (45.8 ± 15.3 , $p=0.03$). However, the patients who did not complete the survey did not differ in terms of gender (61.3% vs 61.1% male, $p=0.99$), pre-transplant SPPB scores (10.9 ± 2.1 vs 11.2 ± 1.8 , $p=0.98$) or pre-transplant balance component scores (3.53 ± 0.94 vs 3.75 ± 0.64 , $p=0.27$). Mean age- and sex-adjusted physical component summary (PCS) score was 50.7 ± 8.7 , and mean age- and sex-adjusted mental component summary (MCS) score was 54.9 ± 8.7 . In univariate linear regression, patients with pre-transplant balance scores < 4 had a 3.9 point lower PCS score compared to patients with pre-transplant balance scores equal to 4 (47.4 vs 51.3, $p=0.09$). Specifically, pre-transplant balance scores < 4 were associated with lower adjusted physical function scores, lower adjusted vitality scores and higher adjusted

role emotional scores (Figure 4, rank-sum p-values <0.05 for all). Other measures of physical function that were associated with lower PCS score included pre-transplant SPPB score < 12 (48.1 vs 51.6, p=0.04) and dominant grip strength (0.14 point increase for every kg increase, p=0.06). Chair rise time and gait speed were not associated with PCS score. On multivariate analysis using stepwise regression and the same variables as in earlier models mentioned above, no measures of physical function were associated with PCS score. Regression diagnostic tests suggest a good fit. Mean adjusted mental component summary (MCS) score was not associated with any pre-transplant physical performance measures (data not shown).

Of the surviving 139 patients, all had follow-up data available 12-months after transplant. The incidence of new-onset diabetes mellitus at 12-months post-transplant was 5.7% (n=8). No relationship between new-onset diabetes mellitus and pre-transplant physical performance measures was observed. Mean 12-month corrected iothalamate clearance among the cohort was 63 ± 17 ml/min/BSA (n=119). No relationship between pre-transplant physical function and 12-month corrected iothalamate clearance was observed. Regression diagnostic tests suggest a good fit.

DISCUSSION

This exploratory study is the first to examine the relationship between pre-transplant performance-based measures of physical function and post-transplant outcomes, including change in physical function after transplant. We found that decreased pre-transplant balance was associated with more than a 3-fold higher risk of longer hospital LOS and nearly a 5-fold higher risk of 30-day rehospitalizations following kidney transplant, independent of other variables including age, gender and diabetes. During the first four months after kidney transplant, measures of physical performance improved significantly, including grip strength, balance, chair stands and gait speed. Male gender and better allograft function were associated with a clinically meaningful improvement in gait speed, whereas diabetes and maintenance steroid use were not. Patients with low pre-transplant physical function reported worse QOL after transplant, including increased levels of fatigue and the belief that their health was limiting their physical activity. However, the relationship between pre-transplant physical function and post-transplant QOL was not significant after adjusting for other variables.

Our study shows that the majority of living donor kidney transplant recipients at our center has surprisingly good physical performance prior to transplant. Nearly 75% of the recipients in our exploratory study had pre-transplant SPPB scores equal to 12 suggesting at most minimal baseline limitations in physical function. This finding likely reflects the characteristics of our study population, including a mean age of only 51 years, a preemptive transplant rate of 56% and a relatively low burden of diabetes and cardiovascular disease. Only one other study has examined SPPB scores in kidney transplant candidates [25]. Among a cohort of patients age 60 or older either being evaluated or waitlisted for kidney transplant, Hartmann et al. found a mean SPPB score was only 8.4 compared to a mean score of 11.1 in our study. However, patients in Hartmann's study were older and likely had more comorbidities. Although no recent studies have specifically examined gait speed in

kidney transplant candidates, Painter et al. found a mean gait speed of 0.86 m/s in a cohort of hemodialysis patients. This gait speed is lower than the mean gait speed (1.18 m/s) found in our study. However, our cohort involved patients healthy enough to proceed with transplant, not all of whom were on dialysis.

Despite the overall health of our cohort, approximately 20% of patients had limitations with balance prior to transplant. Patients with decreased balance were more likely to be older and diabetic. Age and diabetes have both been associated with decreased balance via impairments in the vestibular system [26]. In addition, we found that patients with decreased balance were more likely to have increased levels of cTNT. The relationship between an elevated cTNT and balance may not be clinically significant but could reflect underlying volume overload [27], longer time on dialysis and greater burden of cardiac disease [28].

Interestingly, our exploratory study found that balance testing was more predictive of adverse post-transplant outcomes than other measures of physical function, including total SPPB score, chair rise time, grip strength and gait speed. Pre-transplant balance was the only variable associated with longer hospital LOS, 30-day rehospitalizations and 12-month QOL. Other studies have shown gait speed to be a strong predictor of morbidity across a wide variety of populations [1, 3, 29, 30]. We suspect the lack of relationship between gait speed and post-transplant outcomes reflects the relative health and young age of our cohort and represents a ceiling effect. Thus gait speed assessment alone may not be sufficient for risk stratification in living donor kidney transplant candidates. Rather, more comprehensive measures of physical function testing which incorporate balance testing may be required. No relationship between pre-transplant physical function and 12-month post-transplant outcomes, including mental and physical QOL was identified using multivariable analysis.

Other studies have examined the relationship between physical function and outcomes after kidney transplant using non-performance based measures. For example, Kutner et al. found that lower physical function scores on the Kidney Disease Quality of Life-Short Form instrument were associated with hospitalization/death after kidney transplant [31]. Similarly, Reese et al. found that lower physical function scores on the SF36 were associated with shorter 3-year survival following kidney transplant [32, 33]. In addition to these studies utilizing self-reported measures of physical function, other studies have examined the relationship between pre-transplant frailty and post-transplant outcomes. Frailty is a measure of physiologic reserve based on a combination of unintentional weight loss, weak grip strength, self-reported exhaustion and slow walking speed [34]. Work by McAdams-DeMarco et al. demonstrated that pre-transplant frailty is associated with delayed graft function, rehospitalizations and death after kidney transplant [35–37]. In comparison to these studies, however, our study is unique because it utilizes comprehensive performance-based measures of physical function. Such measures are objective, quantifiable and provide benchmark data for future interventional studies in ways that patient self-report and frailty cannot.

Our study is the first in nearly twenty years to examine change in physical performance measures after kidney transplant. In 1997, Bohannon et al. performed physical performance testing in 21 kidney transplant recipients both pre-transplant and 6 months after transplant.

In contrast to our study, the authors found no significant improvement in balance, gait speed, chair rise time and grip strength following transplant and concluded that transplant was not associated with improvement in physical function. The lack of improvement seen in Bohannon's study may reflect the higher dose of post-transplant steroids used at their center at that time [38]. In contrast, we found that balance, gait speed, chair rise time and grip strength all improved during the first four months post-transplant. A more recent study by McAdams-DeMarco et al. examined change in frailty after kidney transplant and found that frailty does improve by the third month after transplant [39]. However, their study does not describe in detail how individual measures of grip strength and gait speed change post-transplant.

Our study has several strengths. It was a prospective study in which performance-based measures of physical function were performed by a single physical therapist immediately prior to kidney transplant. Testing was performed using infrared photocells and load responsive switch mats to achieve high precision. Limitations of our study include the single-center design, the predominance of preemptive transplants and the exclusion of deceased donor recipients. Thus findings from our study may not necessarily generalize to patients at other centers. However, we suspect that including more patients with a history of pre-transplant dialysis plus deceased donor recipients would only strengthen the relationship between low physical function and adverse post-transplant outcomes given that pre-transplant dialysis was a risk factor for low physical function in our study. Because this study was exploratory, we evaluated a large number of associations which will have to be verified in independent studies. Conclusions regarding balance are limited by the small number of individuals with balance < 4 (n=25). In addition, the stepwise regression used for multivariate analysis depends on the order variables come into the model, potentially limiting our ability to replicate and generalize study results.

Performance-based measures of physical function can quickly and easily identify kidney transplant candidates at risk of longer and more frequent post-transplant hospitalizations and decreased QOL. Further work is needed to determine whether our findings apply to other patient populations and whether other performance-based measures of physical function better stratify patients with fewer ceiling effects. In addition, future studies are needed to determine whether exercise interventions, either before or after kidney transplant, can decrease post-transplant morbidity and improve quality of life.

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Abbreviations

Page	SPPB, Short Physical Performance Battery
GFR	glomerular filtration rate
QOL	quality of life

SF36	Short Form 36 Health Survey
PCS	physical component summary
MCS	mental component summary
cTNT	cardiac troponin T
LOS	length of stay
ESRD	end-stage renal disease
BMI	body mass index

References

1. Hartmann EL, Wu C. The evolving challenge of evaluating older renal transplant candidates. *Advances in chronic kidney disease*. 2010; 17:358–67. [PubMed: 20610363]
2. Tso PL. Access to renal transplantation for the elderly in the face of new allocation policy: a review of contemporary perspectives on “older” issues. *Transplantation reviews*. 2014; 28:6–14. [PubMed: 24262382]
3. Afilalo J, Eisenberg MJ, Morin JF, Bergman H, Monette J, Noiseux N, Perrault LP, Alexander KP, Langlois Y, Dendukuri N, Chamoun P, Kasparian G, Robichaud S, Gharacholou SM, Boivin JF. Gait speed as an incremental predictor of mortality and major morbidity in elderly patients undergoing cardiac surgery. *Journal of the American College of Cardiology*. 2010; 56:1668–76. [PubMed: 21050978]
4. Huisman MG, van Leeuwen BL, Ugolini G, Montroni I, Spiliotis J, Stabilini C, de'Liguori Carino N, Farinella E, de Bock GH, Audisio RA. “Timed Up & Go”: a screening tool for predicting 30-day morbidity in onco-geriatric surgical patients? A multicenter cohort study. *PloS one*. 2014; 9:e86863. [PubMed: 24475186]
5. Robinson TN, Wu DS, Sauaia A, Dunn CL, Stevens-Lapsley JE, Moss M, Stiegmann GV, Gajdos C, Cleveland JC Jr, Inouye SK. Slower walking speed forecasts increased postoperative morbidity and 1-year mortality across surgical specialties. *Annals of surgery*. 2013; 258:582–8. discussion 588–90. [PubMed: 23979272]
6. Arthur HM, Daniels C, McKelvie R, Hirsh J, Rush B. Effect of a preoperative intervention on preoperative and postoperative outcomes in low-risk patients awaiting elective coronary artery bypass graft surgery. A randomized, controlled trial *Annals of internal medicine*. 2000; 133:253–62. [PubMed: 10929164]
7. Hoogeboom TJ, Dronkers JJ, Hulzebos EH, van Meeteren NL. Merits of exercise therapy before and after major surgery. *Current opinion in anaesthesiology*. 2014; 27:161–6. [PubMed: 24500337]
8. Bean JF, Herman S, Kiely DK, Frey IC, Leveille SG, Fielding RA, Frontera WR. Increased Velocity Exercise Specific to Task (InVEST) training: a pilot study exploring effects on leg power, balance, and mobility in community-dwelling older women. *Journal of the American Geriatrics Society*. 2004; 52:799–804. [PubMed: 15086665]
9. Nelson ME, Layne JE, Bernstein MJ, Nuernberger A, Castaneda C, Kaliton D, Hausdorff J, Judge JO, Buchner DM, Roubenoff R, Fiatarone Singh MA. The effects of multidimensional home-based exercise on functional performance in elderly people. *The journals of gerontology Series A, Biological sciences and medical sciences*. 2004; 59:154–60.
10. Pahor M, Blair SN, Espeland M, Fielding R, Gill TM, Guralnik JM, Hadley EC, King AC, Kritchevsky SB, Maraldi C, Miller ME, Newman AB, Rejeski WJ, Romashkan S, Studenski S. Effects of a physical activity intervention on measures of physical performance: Results of the lifestyle interventions and independence for Elders Pilot (LIFE-P) study. *The journals of gerontology Series A, Biological sciences and medical sciences*. 2006; 61:1157–65.
11. Chen JL, Godfrey S, Ng TT, Moorthi R, Liangos O, Ruthazer R, Jaber BL, Levey AS, Castaneda-Sceppa C. Effect of intra-dialytic, low-intensity strength training on functional capacity in adult

- haemodialysis patients: a randomized pilot trial. *Nephrol Dial Transplant*. 2010; 25:1936–43. [PubMed: 20100734]
12. Latham NK, Harris BA, Bean JF, Heeren T, Goodyear C, Zawacki S, Heislein DM, Mustafa J, Pardasaney P, Giorgetti M, Holt N, Goehring L, Jette AM. Effect of a home-based exercise program on functional recovery following rehabilitation after hip fracture: a randomized clinical trial. *JAMA*. 2014; 311:700–8. [PubMed: 24549550]
 13. Puthoff ML. Outcome measures in cardiopulmonary physical therapy: short physical performance battery. *Cardiopulm Phys Ther J*. 2008; 19:17–22. [PubMed: 20467494]
 14. Corsonello A, Lattanzio F, Pedone C, Garasto S, Laino I, Bustacchini S, Pranno L, Mazzei B, Passarino G, Incalzi RA. Pharmacosurveillance In The Elderly Care Pvc Study I. Prognostic significance of the short physical performance battery in older patients discharged from acute care hospitals. *Rejuvenation Res*. 2012; 15:41–8. [PubMed: 22004280]
 15. Hartmann EL, Kitzman D, Rocco M, Leng X, Klepin H, Gordon M, Rejeski J, Berry M, Kritchevsky S. Physical function in older candidates for renal transplantation: an impaired population. *Clin J Am Soc Nephrol*. 2009; 4:588–94. [PubMed: 19261824]
 16. Morie M, Reid KF, Miciek R, Lajevardi N, Choong K, Krasnoff JB, Storer TW, Fielding RA, Bhasin S, Lebrasseur NK. Habitual physical activity levels are associated with performance in measures of physical function and mobility in older men. *Journal of the American Geriatrics Society*. 2010; 58:1727–33. [PubMed: 20738436]
 17. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, Scherr PA, Wallace RB. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *Journal of gerontology*. 1994; 49:M85–94. [PubMed: 8126356]
 18. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *The New England journal of medicine*. 1995; 332:556–61. [PubMed: 7838189]
 19. Wilson DM, Bergert JH, Larson TS, Liedtke RR. GFR determined by nonradiolabeled iothalamate using capillary electrophoresis. *American journal of kidney diseases : the official journal of the National Kidney Foundation*. 1997; 30:646–52. [PubMed: 9370179]
 20. Wauters RP, Cosio FG, Suarez Fernandez ML, Kudva Y, Shah P, Torres VE. Cardiovascular consequences of new-onset hyperglycemia after kidney transplantation. *Transplantation*. 2012; 94:377–82. [PubMed: 22820698]
 21. Ware, JE., Keller, SK. Physical and mental health summary scales: a user's manual. Boston, MA: The Health Institute; 1994.
 22. Ware JE Jr. SF-36 health survey update. *Spine (Phila PA 1976)*. 2000; 25:3130–9. [PubMed: 11124729]
 23. Hardy SE, Perera S, Roumani YF, Chandler JM, Studenski SA. Improvement in usual gait speed predicts better survival in older adults. *Journal of the American Geriatrics Society*. 2007; 55:1727–34. [PubMed: 17916121]
 24. Perera S, Mody SH, Woodman RC, Studenski SA. Meaningful change and responsiveness in common physical performance measures in older adults. *Journal of the American Geriatrics Society*. 2006; 54:743–9. [PubMed: 16696738]
 25. Hartmann EL, Kitzman D, Rocco M, Leng X, Klepin H, Gordon M, Rejeski J, Berry M, Kritchevsky S. Physical function in older candidates for renal transplantation: an impaired population. *Clinical journal of the American Society of Nephrology : CJASN*. 2009; 4:588–94. [PubMed: 19261824]
 26. Agrawal Y, Carey JP, Della Santina CC, Schubert MC, Minor LB. Disorders of balance and vestibular function in US adults: data from the National Health and Nutrition Examination Survey, 2001–2004. *Archives of internal medicine*. 2009; 169:938–44. [PubMed: 19468085]
 27. Hoppe K, Schwermer K, Klysz P, Radziszewska D, Sawatiuk P, Baum E, Kaczmarek J, Roszak M, Kaluzna M, Lindholm B, Pawlaczyk K, Oko A. Cardiac Troponin T and Hydration Status as Prognostic Markers in Hemodialysis Patients. *Blood purification*. 2015; 40:139–145. [PubMed: 26184399]

28. Hickson LJ, Cosio FG, El-Zoghby ZM, Gloor JM, Kremers WK, Stegall MD, Griffin MD, Jaffe AS. Survival of patients on the kidney transplant wait list: relationship to cardiac troponin T. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons*. 2008; 8:2352–9.
29. Carey EJ, Steidley DE, Aqel BA, Byrne TJ, Mekeel KL, Rakela J, Vargas HE, Douglas DD. Six-minute walk distance predicts mortality in liver transplant candidates. *Liver transplantation : official publication of the American Association for the Study of Liver Diseases and the International Liver Transplantation Society*. 2010; 16:1373–8.
30. Martinu T, Babyak MA, O'Connell CF, Carney RM, Trulock EP, Davis RD, Blumenthal JA, Palmer SM. Baseline 6-min walk distance predicts survival in lung transplant candidates. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons*. 2008; 8:1498–505.
31. Kutner NG, Zhang R, Bowles T, Painter P. Pretransplant physical functioning and kidney patients' risk for posttransplantation hospitalization/death: evidence from a national cohort. *Clinical journal of the American Society of Nephrology : CJASN*. 2006; 1:837–43. [PubMed: 17699295]
32. Reese PP, Bloom RD, Shults J, Thomasson A, Mussell A, Rosas SE, Johansen KL, Abt P, Levine M, Caplan A, Feldman HI, Karlawish J. Functional status and survival after kidney transplantation. *Transplantation*. 2014; 97:189–95. [PubMed: 24113514]
33. Reese PP, Shults J, Bloom RD, Mussell A, Harhay MN, Abt P, Levine M, Johansen KL, Karlawish JT, Feldman HI. Functional status, time to transplantation, and survival benefit of kidney transplantation among wait-listed candidates. *American journal of kidney diseases : the official journal of the National Kidney Foundation*. 2015; 66:837–45. [PubMed: 26162652]
34. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, Seeman T, Tracy R, Kop WJ, Burke G, McBurnie MA. Frailty in older adults: evidence for a phenotype. *The journals of gerontology Series A, Biological sciences and medical sciences*. 2001; 56:M146–56.
35. Garonzik-Wang JM, Govindan P, Grinnan JW, Liu M, Ali HM, Chakraborty A, Jain V, Ros RL, James NT, Kucirka LM, Hall EC, Berger JC, Montgomery RA, Desai NM, Dagher NN, Sonnenday CJ, Englesbe MJ, Makary MA, Walston JD, Segev DL. Frailty and delayed graft function in kidney transplant recipients. *Archives of surgery*. 2012; 147:190–3. [PubMed: 22351919]
36. McAdams-DeMarco MA, Law A, King E, Orandi B, Salter M, Gupta N, Chow E, Alachkar N, Desai N, Varadhan R, Walston J, Segev DL. Frailty and mortality in kidney transplant recipients. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons*. 2015; 15:149–54.
37. McAdams-DeMarco MA, Law A, Salter ML, Chow E, Grams M, Walston J, Segev DL. Frailty and early hospital readmission after kidney transplantation. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons*. 2013; 13:2091–5.
38. Bohannon RW, Smith J, Hull D, Palmeri D, Barnhard R. Strength, balance and gait before and after kidney transplantation. *International journal of rehabilitation research. Internationale Zeitschrift für Rehabilitationsforschung Revue internationale de recherches de readaptation*. 1997; 20:199–203. [PubMed: 9226504]
39. McAdams-DeMarco MA, Isaacs K, Darko L, Salter ML, Gupta N, King EA, Walston J, Segev DL. Changes in Frailty After Kidney Transplantation. *Journal of the American Geriatrics Society*. 2015; 63:2152–7. [PubMed: 26416770]

Figure 1.

Length of stay and re-hospitalization rates according to pre-transplant balance score; 25/139 had a balance score < 4.

Figure 2.

Change in Short Physical Performance Battery scores and balance component scores at 4 months following kidney transplant, n=111.

Figure 3.

Relationship between pre-transplant balance and post-transplant SF36 scores ([#]p<0.10; *p<0.05). PCS = physical component summary; PF = physical functioning; RP = role physical; BP = bodily pain; GH = general health; MCS = mental component summary; VT = vitality; SF = social functioning; RE = role emotional; MH = mental health.

Table 1

Baseline demographics

Variable ^I	Total (n=140)
Age	51.2 ± 15.1
Male	86 (61.4)
Caucasian	127 (90.7)
Preemptive	78 (55.7)
Months of pre-transplant dialysis (n=61)	22.2 ± 20.3
Retransplant	21 (15.0)
Diabetes	29 (20.7)
Cause of ESRD	
Glomerulonephritis	58 (41.1)
Polycystic disease	24 (17.1)
Diabetes	16 (11.4)
Unknown	18 (12.8)
Other	24 (17.1)
Coronary artery disease	10 (7.1)
Smoking history	56 (40.0)
Pre-transplant BMI (kg/m ²)	27.2 ± 5.0
Serum albumin (g/dL)	4.2 ± 0.4
Hemoglobin (g/dL)	11.2 ± 1.5
Troponin T (ng/mL)	
<0.01	85 (60.7)
0.01–0.03	25 (17.9)
0.04–0.1	21 (15.0)
>0.1	9 (6.4)
Thymoglobulin	75 (53.6)

^I Mean ± standard deviation for continuous variables; number (%) for categorical variables;

Table 2

Physical function testing pre-transplant and 4-months post-transplant

Test	Pre-transplant ¹	Post-transplant ¹	Change ¹	p-value ²
Total SPPB score ³	11.11 ± 1.84 [4–12]	11.43 ± 1.45 [4–12]	0.38 ± 1.23 [–5–5]	0.002
Balance	3.70 ± 0.72 [1–4]	3.81 ± 0.55 [1–4]	0.14 ± 0.53 [–1–3]	0.008
Chair	3.47 ± 1.16 [0–4]	3.64 ± 0.96 [0–4]	0.21 ± 0.84 [–4–3]	0.01
Gait	3.94 ± 0.26 [2–4]	3.98 ± 0.19 [2–4]	0.04 ± 0.23 [–1–1]	0.10
Chair rise time (s) ⁴	9.13 ± 3.47 [5.10–22.34]	8.42 ± 3.12 [4.56–25.20]	–1.01 ± 2.42 [–11.25–4.39]	<0.0001
Gait speed (m/s)	1.18 ± 0.20 [0.60–1.73]	1.25 ± 0.19 [0.77–1.85]	0.07 ± 0.13 [–0.48–0.43]	<0.0001
Grip strength (kg) ⁵				
Dominant	32.22 ± 11.89 [8.00–73.40]	34.35 ± 11.87 [11.00–69.5]	1.54 ± 4.38 [–12.20–17.80]	0.0003
Non-dominant	28.75 ± 10.79 [4.10–59.60]	31.26 ± 10.82 [10.30–56.80]	1.72 ± 4.44 [–9.10–21.3]	<0.0001

¹Mean ± standard deviation [range];²Paired t-test comparing pre-transplant and 4-month post-transplant results;³n=139 pre-transplant, n= 111 post-transplant, n=111 change in values;⁴n=132 pre-transplant, n= 107 post-transplant, n=104 change in values;⁵n=140 pre-transplant, n= 113 post-transplant, n=112 change in values for dominant hand and n=113 for non-dominant hand

Table 3Baseline demographics according to pre-transplant balance score²

Variable ¹	Balance score < 4 (n=25)	Balance score = 4 (n=114)	p-value ³
Age	62.2 ± 9.5	49.0 ± 15.1	<0.0001
Male	14 (56.0)	71 (62.3)	0.56
Caucasian	22 (88.0)	104 (91.2)	0.62
Preemptive	8 (32.0)	70 (61.4)	0.007
Months of pre-transplant dialysis (n=61)	26.0 ± 26.2	20.6 ± 17.9	0.55
Retransplant	7 (28.0)	14 (12.3)	0.05
Diabetes	14 (56.0)	14 (12.3)	<0.0001
Cause of ESRD			<0.0001
Glomerulonephritis	6 (24.0)	52 (45.6)	
Polycystic disease	0 (0)	24 (21.0)	
Diabetes	8 (32.0)	7 (6.1)	
Unknown	3 (12.0)	15 (13.2)	
Other	8 (32.0)	16 (14.0)	
Coronary artery disease	4 (16.0)	5 (4.4)	0.03
Smoking history	12 (48.0)	43 (37.7)	0.34
Pre-transplant BMI (kg/m ²)	29.1 ± 5.4	26.8 ± 4.8	0.05
Serum albumin (g/dL)	4.1 ± 0.3	4.2 ± 0.4	0.33
Hemoglobin (g/dL)	11.0 ± 1.6	11.3 ± 1.5	0.36
Troponin T (ng/mL)			<0.0001
<0.01	5 (20.0)	80 (70.2)	
0.01–0.03	9 (36.0)	16 (14.0)	
0.04–0.1	8 (32.0)	13 (11.4)	
>0.1	3 (12.0)	5 (4.4)	
Thymoglobulin	13 (52.0)	61 (53.5)	0.89

¹ Mean ± standard deviation for continuous variables; number (%) for categorical variables;² One enrolled patient did not complete pre-transplant SPPB testing;³ Balance score < 4 versus balance score = 4, p-value is from the two-sample t-test or rank-sum test for continuous variables and the chi-squared test for categorical variables

Table 4Association of clinical variables with a pre-transplant balance score < 4¹

Variable	Univariate OR (95% CI)	p-value	Multivariate OR (95% CI) ²	p-value
Age (per 10 years)	2.31 (1.53, 3.85)	0.0003	2.13 (1.34, 3.76)	0.003
Male	0.77 (0.32, 1.88)	0.56		
Caucasian	0.70 (0.20, 3.33)	0.62		
Preemptive	0.30 (0.11, 0.72)	0.0009		
Retransplant	2.78 (0.94, 7.71)	0.05		
Diabetes	9.09 (3.50, 24.61)	<0.0001	4.24 (1.42, 12.99)	0.01
Coronary artery disease	4.15 (0.98, 16.99)	0.04		
Smoking history	1.52 (0.63, 3.66)	0.34		
Pre-transplant BMI (per kg/m ²)	1.10 (1.00, 1.20)	0.04		
Serum albumin (per g/dL)	0.61 (0.19, 2.00)	0.41		
Hemoglobin (per g/dL)	0.87 (0.64, 1.16)	0.35		
Troponin T (ng/mL)		0.0006		0.01
<0.01	Reference		Reference	
0.01–0.03	9.00 (2.75, 32.78)		5.86 (1.51, 24.52)	
0.04–0.1	9.85 (2.86, 37.26)		8.64 (2.11, 39.13)	
>0.1	9.60 (1.62, 53.12)		5.85 (0.89, 35.92)	

¹ n=139, all 95% CI are based on the profile likelihood;² Based on stepwise logistic regression, alpha=0.05 to enter and leave the model