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Changes in Physical Activity Among Spanish Kidney Transplant Recipients: A 12-Month Longitudinal Study

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ABSTRACT

Background: Physical activity is crucial for improving cardiovascular risk and overall health in kidney transplant recipients. However, changes in physical activity before and after transplantation remain underexplored.

Objective: To assess energy expenditure and physical activity before and after kidney transplantation over 1 year, analysing their relationship with cardiovascular risk factors.

Design: Descriptive, longitudinal, prospective study.

Participants: A total of 112 individuals who had received a kidney transplant (aged ≥ 18 years) at a single transplant centre.

Measurements: Sociodemographic and clinical data were extracted from medical records. The International Physical Activity Questionnaire was administered at baseline and at 3, 6 and 12 months after transplantation to evaluate physical activity (as metabolic equivalent minutes per week). Laboratory parameters were also collected.

Analysis: Descriptive statistics summarised participant characteristics. Inferential analyses (chi-square, *t*-tests, ANOVA, Mann–Whitney *U*, Kruskal–Wallis) examined associations between physical activity and clinical variables (significance $p < 0.05$).

Results: Participants had a median age of 58 years; 70.5% were men. Overall physical activity declined at 3 months, rebounded at 6, and decreased again at 12 months, remaining below the levels observed before transplantation. Men, participants not requiring dialysis before transplantation, individuals with overweight, and individuals with a history of cerebrovascular disease exhibited higher physical activity throughout follow-up. Physical activity correlated with certain laboratory parameters, suggesting that better clinical status may foster greater physical activity engagement.

Conclusion: Tailored physical activity targeting comorbidities and nutritional status are recommended to improve long-term outcomes in kidney transplant recipients, particularly among women, older adults, and those with multiple comorbidities.

Abbreviations: BMI, body mass index; CI, confidence interval; CKD, Chronic Kidney Disease; CPG, clinical practice guideline; HD, hemodialysis; IPAQ, International PA Questionnaire; IQR, interquartile range; KDIGO, kidney disease improving global outcomes; KRT, kidney replacement therapy; LPA, low physical activity; MET, metabolic equivalent unit; MPA, moderate physical activity; NODAT, new onset diabetes after transplantation; PA, physical activity; PD, peritoneal dialysis; RRT, renal replacement therapy; VA, vascular access; VPA, vigorous physical activity; WHO, World Health Organization.

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1 | Introduction

Research on physical activity (PA) in kidney transplant recipients has become increasingly relevant in recent years, due to the benefits it can provide in improving their quality of life and general health (Costa-Requena et al. 2020; Masajtis-Zagajewska et al. 2019; Masiero et al. 2020; Zhang et al. 2023). According to WHO recommendations, adults and older people with these chronic conditions should accumulate a minimum of 150–300 min of moderate-intensity aerobic PA, or 75–150 min of vigorous-intensity aerobic PA, or an equivalent combination of moderate- and vigorous-intensity activities, each week to achieve health benefits. As part of their weekly PA, older people with these chronic conditions should engage in varied, multi-component physical activities that prioritise functional balance and moderate- or higher-intensity strength training at least 3 days per week to improve functional capacity and prevent falls (World Health Organization 2020). Most clinical practice guidelines (CPGs) recommend the inclusion of exercise as part of standard care for transplant recipients (Baker et al. 2022; Chen et al. 2019; Muras-Szwedziak et al. 2019).

The KDIGO Guidelines for the Evaluation and Management of Chronic Kidney Disease (CKD) recommend that patients in good cardiovascular health engage in at least 30 min of moderate activity five times per week, equivalent to 450–750 MET-min/week, to maintain a BMI between 20 and 25, adopt a healthy lifestyle, and cease smoking (Kidney Disease: Improving Global Outcomes KDIGO CKD Work Group 2024). However, kidney transplant patients often present with low levels of aerobic capacity, decreased muscle mass, and a sedentary lifestyle, partly owing to prior CKD (Calella et al. 2019; Lendraitiene et al. 2018; van Adrichem et al. 2018) and the use of immunosuppressive medication (Dashti-Khavidaki et al. 2021; Pérez-Granados et al. 2022; Williams et al. 2015). Decreased muscle mass and physical inactivity in these patients have been associated with poorer kidney function and reduced survival following kidney transplantation (Berben et al. 2019; Chen et al. 2019; Rangaswami et al. 2019).

1.1 | Background

Kidney transplantation is considered the best therapeutic option for selected individuals with CKD, offering improved survival rates and better quality of life compared to other kidney replacement therapies (KRT) (Kute et al. 2018). After transplantation, patients often experience improvements in anorexic, hypercatabolic, and psychological states, transitioning from an extremely restricted diet to a more normal, varied diet with fewer food-related restrictions. Nonetheless, controlling diet and weight may remain challenging (Costa-Requena et al. 2017; Ndemera and Bhengu 2017; Nutting et al. 2021; Tantisattamo 2017).

An increase in body weight after kidney transplantation has been observed and is associated, among other factors, with a decrease in PA during the first postoperative months, an increase in appetite, and the use of immunosuppressive therapy (Thomas-Fonseca et al. 2021). While obesity may confer a protective effect against all-cause mortality in pre-dialysis and haemodialysis patients, this benefit does not extend to transplant recipients (Ladhani et al. 2017), as it is linked to reduced graft and patient survival, even with a functioning kidney (Bellini et al. 2023; Devine et al. 2019; Forte et al. 2020; Kassam et al. 2020). Currently, transplant recipients tend to be older and often have more comorbidities; although advances in immunosuppression and treatment have led to prolonged graft survival, minimising cardiovascular risk factors through lifestyle changes (e.g., balanced diet, regular PA) and adjusting immunosuppressive therapy remain crucial (Cheung and Tang 2022; Takahashi et al. 2018; Bellizzi et al. 2014).

PA is a key public health strategy known to help control cardiovascular risk factors and improve aerobic and functional capacities (Kang et al. 2019; Roi et al. 2014; Yanishi et al. 2017). The World Health Organization (WHO) defines PA as any bodily movement produced by skeletal muscles that leads to energy expenditure and improved health (World Health Organization 2020). It helps prevent overweight and obesity and reduces stress, which is especially beneficial for kidney transplant recipients (Billany et al. 2025; González et al. 2023; Villanego et al. 2020; Yuguero-Ortiz et al. 2021). Conversely, physical inactivity—a major risk factor for global mortality—is associated with worse kidney function and decreased survival post-transplant (García and González-Jurado 2017; Ponticelli and Favi 2021). Indeed, inactive patients tend to present with lower muscle mass and poorer outcomes (Rangaswami et al. 2019; Schardong et al. 2018). In contrast, recipients who engage in regular PA show higher aerobic capacity, greater muscle strength, and reduced morbidity and mortality (Calella et al. 2019; Kang et al. 2020; Lima et al. 2018; Totti et al. 2020).

Despite extensive research on quality of life in kidney transplant recipients, further investigation is needed into the impact of day-to-day PA. Assessing PA in this population is an effective strategy to understand and evaluate changes before and after kidney transplantation and to elucidate the influence of underlying morbidity, cardiorespiratory status, and overall health (Dierkes et al. 2018; Lima et al. 2018; Raymond et al. 2016; Seoane-Pillado et al. 2017). Accordingly, this study aims to measure energy expenditure and PA levels before and following transplantation, as well as their trajectory during the first postoperative year, and to analyse their relationship with cardiovascular risk factors such as hypertension, diabetes mellitus, cardiovascular events, dyslipidaemia, overweight, and obesity.

2 | Materials AND Methods

2.1 | Study Design and Participants

A descriptive, longitudinal, prospective study was conducted among kidney graft recipients aged 18 years or older at the Hospital Universitario Miguel Servet (Zaragoza, Spain) between September 2020 and August 2023. It is a tertiary-level, university-affiliated hospital and the referral centre for kidney transplantation in Aragón, with 88 kidney transplants and 8 heart transplants performed in 2024 (Organización Nacional de Trasplantes 2025). The study adhered to the STROBE recommendations for reporting observational studies (von Elm et al. 2007). The inclusion criteria required participants to have signed the informed consent form. The participants were

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recruited during their preoperative hospitalisation. Individuals with an upper and/or lower limb amputation were excluded.

2.2 | Variables and Data Collection

Sociodemographic and clinical variables were obtained from participants' clinical records, including age, sex, anthropometric measurements (height, weight, BMI, obesity rate), and relevant comorbidities (hypertension, diabetes, dyslipidaemia, cardiovascular disease, cardiorespiratory disease, cerebrovascular accident). Information on toxic habits (tobacco use, ethanol consumption), waiting time until transplantation, and type of pre-transplant kidney replacement therapy (none, peritoneal dialysis, or haemodialysis) was also recorded. Additionally, the type of kidney transplant (living donor or deceased donor) was obtained; however, due to the low proportion of living donor cases, this variable was not included in the statistical analysis. Analytical data included urea, creatinine, total protein, albumin, ferritin, haemoglobin, haematocrit, and HbA1c levels, these data were collected during the reception and preparation the day before surgery, and at 3, 6 and 12 months in the same week corresponding to the scheduled review with the nephrologist.

PA was assessed using the International Physical Activity Questionnaire (IPAQ) (Craig et al. 2003). Patients aged 18–65 completed the standard Spanish version (Román Viñas et al. 2013), whereas those over 65 answered the IPAQ-E (Rubio Castañeda et al. 2017) (Appendices 1 and 2). The questionnaire evaluated PA before transplantation and was administered retrospectively through personal interviews conducted by the principal investigator before hospital discharge. Metabolic equivalent units (METs), which represent the energy cost of physical activities as multiples of the resting metabolic rate (with 1 MET corresponding to the energy expended at rest; moderate activities ranging from 3 to 6 METs; and vigorous activities exceeding 6 METs), were calculated to estimate energy expenditure per minute and per week. MET-minutes were obtained by multiplying the MET value of each activity by the number of minutes spent on that activity per day or week. PA was categorised as high, moderate, or low (Table 1) according to IPAQ criteria, where moderate-intensity activities include those causing moderate increases in breathing or heart rate (such as brisk walking, dancing, or recreational cycling), and vigorous-intensity activities are those causing substantial increases in breathing or heart rate (such as running, fast cycling, or aerobic exercises).

2.3 | Data Analysis

For the descriptive analysis, qualitative variables are expressed as absolute and relative frequencies (n, %), whereas quantitative variables are described via measures of central tendency and dispersion (mean ± standard deviation for normally distributed data, and median [interquartile range (IQR)] for non-normally distributed data). Inferential analyses compared proportions when both variables were qualitative (Chi-square test or Fisher's exact test), and compared means or ranks for quantitative variables. Parametric tests (Student's t-test, ANOVA) were used for normally distributed data, and non-parametric tests (Mann–Whitney U, Kruskal–Wallis) were used for non-normal distributions. A $p < 0.05$ was considered statistically significant, with a 95% confidence interval (CI). Statistical analyses were performed using SPSS version 25.

2.4 | Ethical Considerations

Before data collection, participants were informed of the study's aims and procedures, and they provided written informed consent. They were also advised of their right to withdraw from the study at any time without any negative consequences. Permissions to use the IPAQ and IPAQ-E questionnaires were obtained from the respective authors. All procedures followed the principles of the Declaration of Helsinki (WHO, 2013), and patient anonymity was ensured by omitting names, initials, and medical record numbers. The study was approved by the hospital's management and the Ethics Research Committee of the Autonomous Community of Aragon (C.P. – C.I. PI20/278).

3 | Results

A total of 112 kidney transplant patients participated in this study. All the eligible patients agreed to take part and were recruited to participate in this investigation; no patients were

TABLE 1 | Physical activity categories.

Category	Characteristics
Low (< 600 METs)	No physical activity.
	Insufficient physical activity to reach categories 2 or 3.
Moderate (600-1499 METs)	Vigorous physical activity on 3 or more days for at least 25 min each day.
	Moderate physical activity and/or walking on 5 or more days for at least 30 min each day.
	Combination of walking and/or moderate to vigorous physical activity, achieving an energy expenditure of at least 600 METs per minute and per week on 5 or more days.
Vigorous (> 1500 METs)	Vigorous physical activity on at least 3 days per week, achieving an energy expenditure of 1500 METs per minute and per week.
	Combination of walking and/or moderate to vigorous physical activity on 7 or more days per week, achieving an energy expenditure of at least 3000 METs per minute and per week.

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lost to follow. Over two-thirds (70.5%) were men, with a median age of 58 years (IQR: 19.3), ranging from 18 to 80; the majority (70.5%) were under 65 years of age. The main causes of CKD were glomerulopathies (27.68%), followed by unspecified causes (21.43%), polycystic kidney disease (12.50%), and diabetic nephropathy (12.50%). Overall, 65.2% of participants received kidney replacement therapy (KRT) via haemodialysis (HD), 26.8% via peritoneal dialysis (PD), and 8.0% did not require dialysis before transplantation. Nearly half had an arteriovenous fistula (44.6%) for vascular access, and the majority (88.4%) underwent their first kidney transplant. Most transplants were from deceased donors (89.3%). The median waiting time for transplantation was 326 days (IQR: 506; range: 1–2013), with men waiting longer (366 days, IQR: 481) than women (231 days, IQR: 456). In addition, patients under 65 years of age remained on the waiting list longer (387 days, IQR: 524) compared to those over 65 (194 days, IQR: 256), a difference that reached statistical significance ($p = 0.010$).

Regarding clinical comorbidities, 90.2% of the sample presented with arterial hypertension, while 52.7% had dyslipidaemia and half had a BMI above 25 kg/m² (34.0% overweight, 14.3% obese). Ischaemic heart disease was found in 26.0% of patients, 19.6% had diabetes, 18.0% reported toxic habits, 13.4% had respiratory disease, and 4.5% had a history of cerebrovascular accident. Notably, men had significantly higher mean BMI values than women (25.70 ± 4.03 vs. 23.60 ± 5.06; $p = 0.020$). When BMI was categorised, nearly half of the participants were of normal weight (47.3%), followed by overweight (34.0%) and obese (14.3%), with a statistically significant distribution in the gender distribution ($p = 0.007$). Analytical values revealed above-normal averages for ferritin (384.85 ng/mL), creatinine (6.08 mg/dL), and serum urea (107.00 mg/dL). Total protein (6.60 g/dL), albumin (4 g/dL), and HbA1c (5.30%) remained within normal ranges, whereas haemoglobin (11.90 g/dL) and haematocrit (35.65%) were slightly low, whereas women had lower serum creatinine levels ($p = 0.016$). Table 2 summarises these baseline sociodemographic and clinical variables.

When examining PA in relation to qualitative variables, higher levels of PA were noted among men, participants aged over 65 years, those not undergoing dialysis, individuals with an arteriovenous fistula, and those classified as overweight. Greater PA was also observed among hypertensive participants, individuals without diabetes or dyslipidaemia, and those without ischaemic heart disease or respiratory disease. Moreover, participants reporting toxic habits or a history of stroke likewise displayed higher PA levels. No statistically significant differences were identified between the dependent variable (MET-min/week) and the categorical independent variables under study (Table 3).

Globally, the median pre-transplant PA was 1735 MET-min/week (IQR: 1126–2922). This figure decreased to 1386 (IQR: 1040–2079) at 3 months post-surgery, rebounded to 1906 (IQR: 1386–2392) at 6 months, and then declined again at 12 months to 1386 (IQR: 1040–2099) MET-min/week. These 12-month values did not return to pre-transplant levels (Table 4).

When PA was categorised, more than half of the patients (53%) reported vigorous activity before transplantation, decreasing to 46% at 3 months, then rising to 61% at 6 months, and falling back to 45% at 12 months. Around 31% of participants reported moderate PA before transplantation, increasing to 43% at 3 months, dropping again to 31% at 6 months, and finally rising to 48% 1 year after transplantation. At baseline, 16% of the population were ($n = 18$), but this proportion dropped progressively to 7.1% ($n = 8$) by the end of the first year (Table 5).

When comparing PA changes over the 1-year follow-up with the qualitative independent variables, men reported higher PA levels than women at all time points. Statistically significant differences ($p = 0.033$) were found at 12 months, although both groups had lower PA levels than before transplantation (Table 6). Examining PA evolution by gender (Figure 1) revealed that men's PA declined at 3 months from pre-transplant levels, whereas women's PA levels remained stable. At 6 months, both men and women recorded marked increases, without significant differences. Although significant differences emerged in the male subgroup across the four time points ($p = 0.044$).

Analysing PA by age group (Figure 2) showed that participants aged over 65 had higher PA at all time points. Their PA peaked at 3 months—2079 (IQR: 1107) MET-min/week—and remained stable at 6 months, before declining considerably at the end of the first year. Those younger than 65 showed a decrease in PA at 3 months—1386 (IQR: 1039)—followed by a recovery at 6 months, yet ultimately ended up below their pre-transplant baseline by 12 months. Significant intra-group differences were detected among participants under 65 ($p = 0.032$), whereas no statistically significant differences emerged between the two age groups.

In terms of RRT (Figure 3), participants not requiring dialysis had higher PA at the first two measurements compared to those undergoing HD or PD, yet displayed a consistent decrease over time and remained stable at 12 months. PD and HD patients followed a similar pattern. No statistically significant differences were identified between PA and RRT.

Regarding BMI, overweight individuals displayed the highest PA levels at each measurement period. Although their PA declined by the 12-month assessment, the mean PA in this group remained higher than in the other BMI categories (Figure 4). Participants with low body weight experienced a notable PA recovery at 6 months, offsetting the decline they had shown at 3 months, and by the end of the study their PA levels were comparable to other groups. Statistically significant differences in PA by BMI category were observed at 6 months ($p = 0.007$).

Within the comorbidity analysis, participants with hypertension showed significant intra-group differences in PA over time ($p = 0.026$). Similarly, significant changes in PA were found among those without diabetes ($p = 0.007$), without respiratory disease ($p = 0.018$), without stroke ($p = 0.023$), and those without de novo post-transplant diabetes or toxic habits ($p = 0.024$).

Finally, correlations between PA and quantitative independent variables indicated a statistically significant positive correlation between serum urea levels and pre-transplant PA ($r = 0.207$, $p = 0.029$). At 3 months, a positive correlation was found

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TABLE 2 | Baseline socio-demographic and clinical characteristics.

		n (%) 112 (100%)	Men 79 (%)	Women 33 (%)	*p*
Age (categorized)	18–64	79 (705)	57 (722)	22 (667)	0562^{x}
	≥ 65	33 (295)	22 (278)	11 (333)	
Kidney replacement therapy	Non-dialysis	9 (8.1)	6 (7.6)	3 (9.1)	0.784^{+}
	Peritoneal dialysis	30 (26.8)	23 (29.1)	7 (21.2)	
	Haemodialysis	73 (65.2)	50 (63.3)	23 (69.7)	
Transplant previous	Non-previous transplant	99 (88.4)	71 (89.9)	28 (84.8)	0.449^{x}
	Transplant previous	13 (11.6)	8 (10.1)	5 (15.2)	
Vascular access	No vascular Access	39 (34.8)	29 (36.7)	10 (30.3)	0.255^{+}
	Arteriovenous fistula	50 (44.6)	37 (46.8)	13 (39.4)	
	Catheter	23 (20.5)	13 (16.5)	10 (30.3)	
BMI	Under weight	5 (4.5)	1 (1.3)	4 (12.1)	0.007^{+}
	Normal weight	53 (47.3)	34 (43.0)	19 (57.6)	
	Overweight	38 (34.0)	33 (41.8)	5 (15.2)	
	Obesity	16 (14.3)	11 (13.9)	5 (15.2)	
Patients with hypertension		101 (90.2)	71 (70.3)	30 (29.7)	0.867^{x}
Patients with dyslipidaemia		59 (52.7)	43 (72.9)	16 (27.1)	0.566^{x}
Patients with previous diabetes		22 (19.6)	16 (72.7)	6 (27.3)	0.801^{x}
Patients with Ischemic Heart disease		29 (26.0)	21 (26.6)	8 (24.2)	0.797^{x}
Patients with respiratory disease		15 (13.4)	14 (17.7)	1 (3.0)	0.037^{x}
Patients with cerebrovascular accident		5 (4.5)	3 (29.0)	2 (40.0)	0.597^{x}
Patients with toxic habit		20 (18.0)	16 (80.0)	4 (20.0)	0.306^{x}
Time on waiting list (days)$^{+}$		326 ± 506	366 ± 481	231 ± 456	0.964^{U}
BMI((kg(m2)*		25.10 ± 4.45	25.70 ± 4.03	23.60 ± 5.06	0.020^{T}
Ferritin (15-200 ng(mL)$^{+}$		384.85 ± 445.20	355 ± 467	387 ± 362	0.792^{U}
Urea (17-43 mg(dL)$^{+}$		107.00 ± 80.00	112.00 ± 79.50	99.00 ± 69	0.165^{U}
Creatinine (0.51-0.95 mg(dL)$^{+}$		6.08 ± 3.03	6.21 ± 3.78	5.40 ± 2.83	0.016^{U}
Total. protein (6.6-8.3 g(dL)*		6.60 ± 0.80	6.70 ± 0.85	6.60 ± 0.80	0.196^{T}
Albumin (3.5-5.2 g(dL)*		4.00 ± 0.60	4.00 ± 0.60	3.90 ± 0.60	0.128^{T}
Glycated haemoglobin (HbA1c)$^{+}$		5.30 ± 0.71	5.20 ± 0.70	5.30 ± 0.80	0.934^{U}
Haemoglobin (g(dL)*		11.90 ± 1.92	12.00 ± 1.90	11.7 ± 2.10	0.380^{T}
Haematocrit (%)$^{+}$		35.65 ± 5.12	35.9 ± 4.90	35.50 ± 5.70	0.699^{U}

Abbreviations: x, Chi-cuadrado; +, Fisher's Test; *T*, Student's *T* test; *U*, Mann–Whitney's *U* test.

between haematocrit and PA ($r = 0.214$, $p = 0.023$), and at 12 months between albumin and PA ($r = 0.196$, $p = 0.038$). None of the remaining variables showed significant correlations with PA (Table 7).

4 | Discussion

Our findings on sex distribution align with prior research indicating a higher incidence and faster progression of CKD in men, even though women are often found to have a greater overall prevalence of the disease (Gorostidi et al. 2018; Melek et al. 2018; Melsom et al. 2022; Swartling et al. 2021). These differences may reflect both biological and behavioural factors (Carrero et al. 2018; Chesnaye et al. 2024). Notably, our proportion of participants aged over 65 exceeded the usual 15%–20% cited in other cohorts, suggesting that expanding eligibility criteria and changing demographics may be increasing the number of older individuals receiving kidney transplants (Arias-Cabrales et al. 2018; Estupiñán-Bohórquez et al. 2021; Lehner et al. 2018). Additionally, we observed higher overweight and obesity rates among men, in line with earlier studies (Pedreira-Robles et al. 2024).

PA levels declined at 3 months' post-transplant—likely reflecting the immediate recovery period—then partially recovered at 6 and 12 months, yet remained below pre-transplant values. This trajectory mirrors the findings of (Kumar et al. 2019),

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TABLE 3 | Pre-transplant PA.

	n (%)	Median (IQR)	*p*
Sex			
Men	79 (70.5%)	2072 (2026)	0.059*
Women	33 (29.5%)	1386 (1287)	
Age			
18–64	79 (70.5)	1732 (1735)	0.980*
≥ 65	33 (29.5)	1848 (1740)	
Kidney replacement therapy			
Non-dialysis	9 (8.1)	2619 (1386)	
Peritoneal dialysis	30 (26.8)	1682 (1609)	0.576^{+}
Haemodialysis	73 (65.2)	1533 (1973)	
Vascular access			
No vascular access	39 (34.8)	1746 (15679)	
Arteriovenous fistula	50 (44.6)	1815 (1843)	0.872^{+}
Catheter	23 (20.5)	1386 (2135)	
BMI			
Under weight	5 (4.5)	1040 (990)	
Normal weight	53 (47.3)	1778 (1732)	0.196^{+}
Overweight	38 (33.9)	1909 (3132)	
Obesity (BMI ≥ 30)	16 (14.3)	1386 (1439)	
Previous transplant			
Yes	99 (88.4)	1732 (1748)	0.816*
No	13 (11.6)	1746 (1733)	
Hypertension			
No	11 (9.8)	1386 (3499)	0.879*
Yes	101 (90.2)	1737 (1612)	
Previous Diabetes			
No	90 (80.4)	1762 (1773)	0.524*
Yes	22 (19.6)	1386 (1471)	
Dyslipidemia			
No	53 (43.7)	1746 (1896)	0.610*
Yes	59 (52.7)	1626 (1733)	
Ischemic Heart disease			
No	83 (74.1)	1746 (1615)	0.821*
Yes	29 (25.9)	1386 (3113)	
Respiratory disease			
No	97 (86.6)	1746 (1777)	0.488*
Yes	15 (13.4)	1386 (1319)	
Cerebrovascular accident			
No	107 (95.5)	1533 (1806)	0.077*
Yes	5 (4.5)	2772 (4251)	
Toxic habit			
No	92 (82.1)	1735 (1613)	0.994*
Yes	20 (17.9)	1853 (2827)	

Abbreviations: *, Mann Whitney U test; +, Kruskal Wallis test.

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TABLE 4 | Global mets min./week by period.

Time	0 months	3 months	6 months	12 months
Median (IQR)	1735 (1126–2922)	1386 (1040–2079)	1906 (1386–2392)	1386 (1040–2099)
Range	0–11,970	0–8316	0–8316	132–10,260

TABLE 5 | Mets categorised by type of activity according to time periods.

Time	0 months	3 months	6 months	12 months
Category	*n* (%)	*n* (%)	*n* (%)	*n* (%)
VPA	59 (53%)	52 (46%)	68 (61%)	50 (45%)
MPA	35 (31%)	48 (43%)	35 (31%)	54 (48%)
LPA	18 (16%)	12 (11%)	9 (8.0%)	8 (7.1%)
Total	112 (100%)	112 (100%)	112 (100%)	112 (100%)

Note: Values are shown as percentages.
Abbreviations: LPA, low physical activity (< 600 METs); MPA, moderate physical activity (600–1499 METs min/week); VPA, vigorous physical activity (> 1500 METs min/week).

who used the same questionnaire, although (Görücü and Ordin 2022) reported higher PA levels at 1 year in a different setting. Our data also show that vigorous physical activity (VPA) decreased substantially by 12 months, potentially due to immunosuppressive side effects, fear of graft injury, or insufficient rehabilitation support (Zelle et al. 2016; Zhang-Xu et al. 2011). By contrast, the proportion of individuals performing moderate PA (MPA) rose from 31% to 48% over the same period, a figure still lower than the 51.6%–59% range noted in other investigations (Masiero et al. 2020; Raymond et al. 2016).

Interestingly, a smaller percentage of participants in our cohort were classified as inactive compared to other studies, which have reported higher inactivity or predominantly low-intensity PA (Byambasukh et al. 2020; Kumar et al. 2019), with men consistently reported more total PA than women (Kang et al. 2019; Kumar et al. 2019). Although this study did not specifically explore the reasons behind such disparities, factors such as cultural expectations, self-efficacy, and social support may play pivotal roles in exercise behaviours (Costa-Requena et al. 2017; Wang 2024; Zelle et al. 2016).

Older adults, individuals not undergoing dialysis, and those with a history of transplantation presented distinct PA patterns, in agreement with Masiero et al. (2020) and Wilkinson et al. (2021). However, these findings differ from Görücü and Ordin (2022), who found no association between PA and variables such as age, sex, or donor type. Participants with hypertension, a history of stroke, or smoking habits showed higher PA levels, possibly indicating that these individuals are motivated to exercise to manage their comorbid conditions (van Adrichem et al. 2018).

In our sample, overweight participants exhibited the highest PA levels across all time points, whereas underweight individuals made a marked improvement by 12 months, nearly matching the PA levels of other BMI groups. While multiple studies have documented relationships between BMI and PA, the dynamics of weight gain and BMI control may be especially complex in kidney transplant recipients, given immunosuppressive therapy, dietary factors, and comorbidities (Martín Salvador 2019). An international randomised clinical trial by Kang et al. (2020) further underscores the relevance of PA in this population, demonstrating reduced cardiovascular events and mortality among more active patients. Improvements in left ventricular function and reduced ventricular hypertrophy are among the cardioprotective benefits linked to higher PA (Bishop et al. 2023; Durán-Sáinz et al. 2023), a vital outcome given the high cardiovascular risk in transplant recipients (Thomas-Fonseca et al. 2021).

With respect to laboratory parameters, we found a positive correlation between pre-transplant PA and serum urea, while haematocrit and albumin levels correlated with PA at 3 and 12 months, respectively. These associations may reflect better baseline health, nutritional status, or both, allowing patients to engage in more intense or consistent exercise (Flores-Ojeda 2023; Silva-Filho et al. 2019). However, they do not necessarily imply a causal relationship, and further prospective or interventional research would help clarify the direction of influence.

PA can vary considerably among transplant recipients due to psychological factors, such as anxiety about graft rejection, as well as the quality and frequency of patient education on exercise benefits. Nursing professionals are uniquely positioned to identify barriers and facilitators to PA throughout the transplant journey (Bates et al. 2024). Person-centred interventions, aligned with patient needs and preferences, can reduce anxiety, improve motivation, and foster long-term adherence (Antoun et al. 2023; Molsted et al. 2023).

4.1 | Limitations and Strengths

This study has several limitations. For instance, growing awareness of PA benefits might lead individuals to

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TABLE 6 | Evolution of PA in METs by time periods according to qualitative variables.

Variable	0 months	*p*	3 months	*p*	6 months	*p*	12 months	*p*	*p* ANOVA
Sex									
Men	2072/2026	0.059	1546/813	0.148	2079/1240	0.265	1732/1050	0.033	0.044
Women	1386/1287		1386/1386		1848/1040		1386/556		0.179
Age								0.323	
18-64	1732/1735	0.98	1386/1039	0.394	1866/1022	0.773	1386/1308		0.032
≥ 65	1848/1740		2079/1107		2079/1292		1386/1040		0.141
KRT				0.519					
Non-dialysis	2619/1386	0.576	2079/947		1626/594	0.953	1626/1053	0.400	0.338
PD	1682/1609		1386/1039		1857/1003		1560/693		0.245
HD	1533/1973		1398/1089		1964/990		1386/1040		0.079
Vascular access									
Non VA	1746/1567	0.872	1386/973	0.981	1848/899	0.968	1626/813	0.253	0.151
Fav	1815/1843		1386/1596		2021/803		1386/1040		0.126
Catheter	1386/2135		1980/1047		1848/1782		1386/1757		0.383
BMI				0.080					
Under weight	1040/990	0.196	495/1683		1386/1040	0.007	1386/693	0.434	0.926
Normal weight	1778/1732		1425/1039		2079/933		1485/1337		0.106
Overweight	1909/3132		2030/1377		2079/1386		1516/693		0.254
Obesity (BMI ≥ 30)	1386/1439		1320/644		1386/815		1386/482		0.191
Previous transplant									
No	1732/1748	0.816	1470/973	0.077	2079/1073	0.208	1386/1110	0.574	0.076
Yes	1746/1733		1188/644		1546/891		1386/1089		0.120
Hypertension									
No	1386/3499	0.879	1470/1041	0.894	2079/1113	0.887	1386/1238	0.712	0.689
Yes	1737/1612		1386/1039		1848/1053		1386/1040		0.026
Previous diabetes									
No	1762/1773	0.610	1386/1045	0.293	1906/979	0.950	1386/1165	0.822	0.007
Yes	1386/1471		2030/1289		1883/1298		1436/957		0.787
Dyslipidemia									
No	1746/1896	0.524	1470/1287	0.698	1964/1386	0.242	1485/1386	0.074	0.082
Yes	1626/1733		1386/973		1848/792		1386/1040		0.200
Ischemic heart disease									
No	1746/1615	0.821	1398/1039	0.569	1964/1032	0.553	1386/1230	0.614	0.105
Yes	1386/3113		1386/1386		1848/942		1485/1089		0.101
Respiratory disease									
No	1746/1777	0.488	1386/1039	0.911	1964/1074	0.210	1386/1280	0.172	0.018
Yes	1386/1319		1980/1749		1626/1163		1386/891		0.408
Cerebrovascular accident									
No	1533/1806	0.077	1386/1039	0.932	1964/1022	0.865	1386/1080	0.275	0.023
Yes	2772/4251		1386/693		1485/462		2079/693		0.106
Toxic habit						0.364		0.420	
No	1735/1613	0.994	1386/1041	0.493	1848/956		1386/1159		0.024
Yes	1853/2827		2030/850		2079/1136		1436/1126		0.442

(Continues)

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TABLE 6 | (Continued)

Variable	0 months	p	3 months	p	6 months	p	12 months	p	p ANOVA
NODAT									
No	1742/1796	0.684	1486/902	0.159	2021/1088	0.188	1516/1028	0.044	0.039
Yes	1460/1699		1386/1236		1766/1213		1386/347		0.293

Abbreviations: ANOVA, analysis of variance; BMI, body mass index; HD, haemodialysis; KRT, kidney replacement therapy; NODAT, New Onset Diabetes After Transplantation; PD, peritoneal dialysis; VA, vascular access.

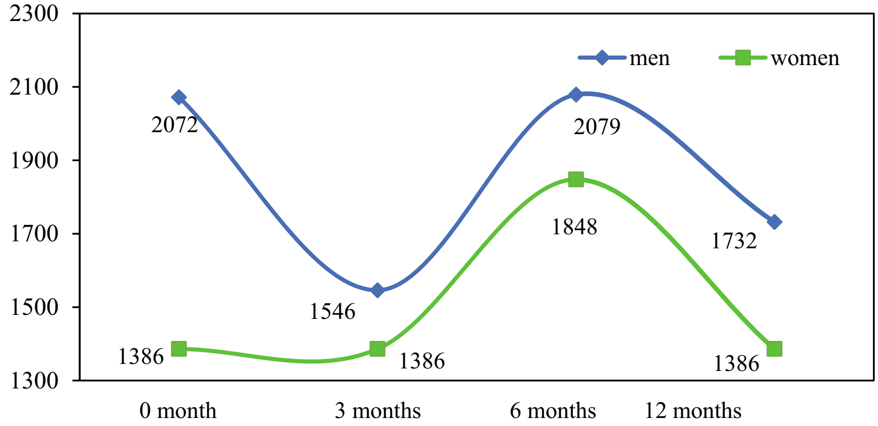

FIGURE 1 | Evolution of PA by sex. PA, physical activity.

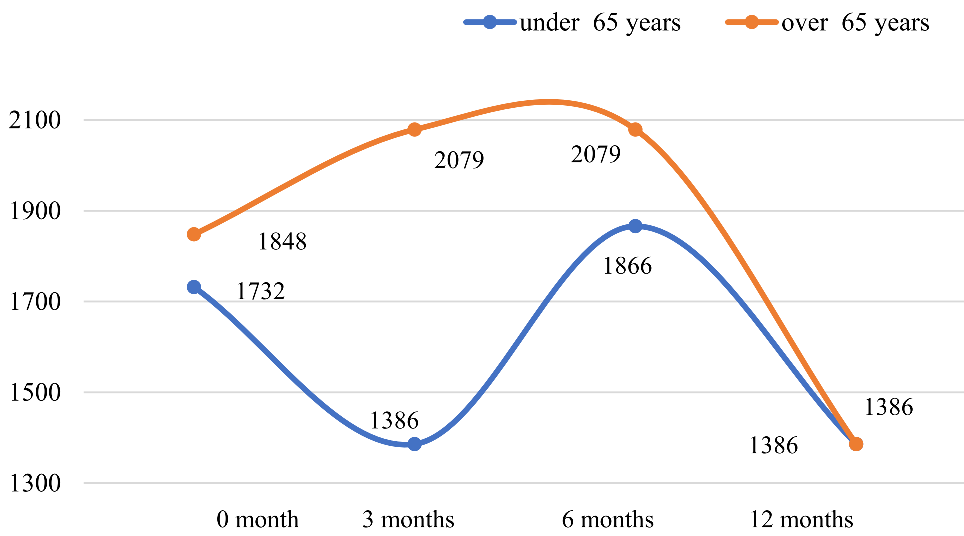

FIGURE 2 | Evolution of PA by age group. PA, physical activity.

overestimate their level of activity. Another limitation is the use of self-report questionnaires to assess PA. A potential limitation of this study is that PA was assessed retrospectively, after transplantation, based on patient recall. This may have introduced recall bias, particularly in older participants. Although validated and widely used, questionnaires such as the IPAQ may introduce recall bias and subjective inaccuracies compared with objective measurements such as those obtained via accelerometers. Nevertheless, the use of accelerometers also presents limitations, including economic constraints and the challenges associated with device placement and compliance among patients awaiting transplantation. Moreover, psychological factors and prior health education regarding the benefits of PA were not assessed as dependent variables, which may have influenced participants' PA levels. Finally, our study did not assess dietary habits or adherence to nutritional recommendations. Although nutritional counseling is an essential component of kidney replacement therapy, each modality involves specific dietary guidelines, and evaluating their implementation was beyond the scope of this study.

On the positive side, our sample comprised patients who were independent in their daily activities, thus minimising limitations in carrying out daily tasks and returning to work post-transplant.

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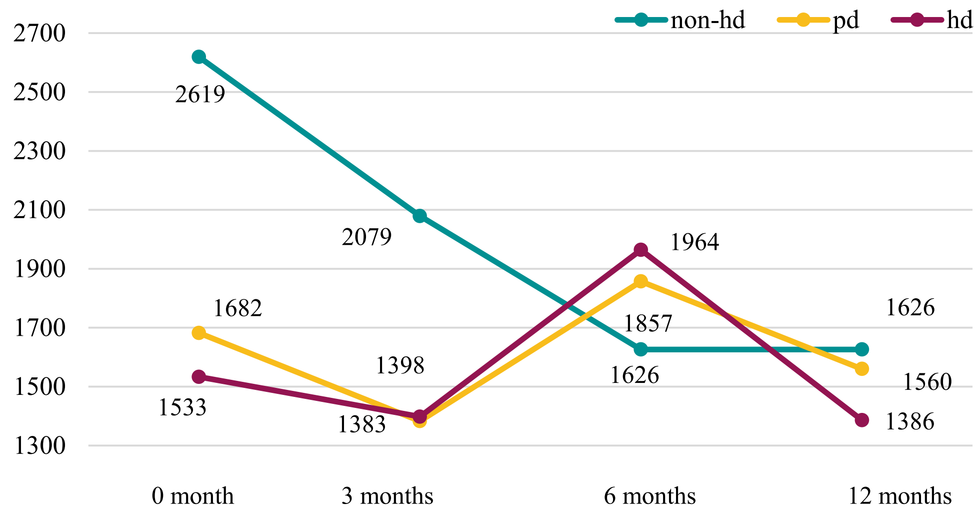

FIGURE 3 | Evolution of PA by RRT. PA, physical activity; RRT, Renal Replacement Therapy.

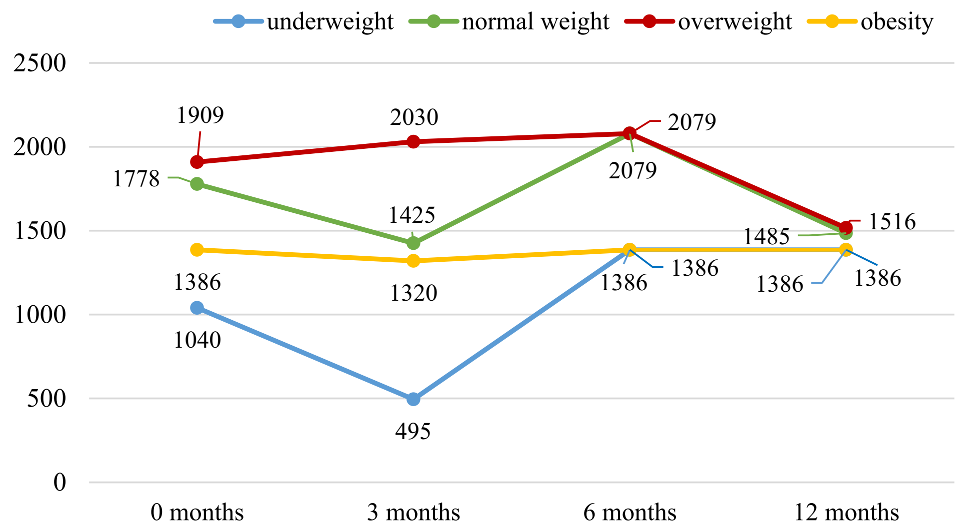

FIGURE 4 | Evolution of PA by BMI. BMI, body mass index; PA, physical activity.

TABLE 7 | Correlation between PA and analytical variables.

Time period	0 months		3 months		6 months		12 months	
Variable	Spearman	*p*	Spearman	*p*	Spearman	*p*	Spearman	*p*
Ferritin	−0.050	0.599	−0.088	0.363	−0.027	0.779	−0.092	0.350
Urea	0.207	0.029	−0.090	0.346	0.065	0.498	0.005	0.958
Creatinine	0.083	0.386	−0.002	0.987	−0.046	0.627	0.080	0.401
Proteins	0.083	0.384	0.086	0.369	−0.047	0.625	0.131	0.167
Albumin	−0.047	0.626	0.101	0.287	0.016	0.868	0.196	0.038
Haemoglobin	0.054	0.569	0.174	0.067	0.117	0.219	0.074	0.441
Haematocrit	0.075	0.431	0.214	0.023	0.144	0.130	0.054	0.570
Glycated haemoglobin	0.115	0.228	0.096	0.329	0.026	0.796	−0.124	0.204

5 | Conclusion

Our findings indicate that men, individuals with a pre-transplant non-dialysis status, those with overweight, and patients with a history of cerebrovascular disease exhibited higher levels of PA throughout the follow-up period. These observations underscore the need to tailor post-transplant PA programmes to each patient's comorbidities, weight status, and

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overall health profile to optimise rehabilitation and long-term well-being. Given the variability in PA patterns—particularly among women, older adults, and patients with complex comorbid conditions—healthcare professionals, especially nurses, should identify both facilitators and barriers to regular exercise. By adapting PA prescriptions to individual circumstances and providing ongoing education and support, it may be possible to enhance adherence, mitigate cardiovascular and metabolic risks, and ultimately improve graft function and patient survival. These findings should serve as a foundation for offering personalized exercise recommendations as soon as patients are added to the transplant waiting list, with a focus on encouraging PA especially among those with lower baseline activity levels.

Future research should explore how structured exercise interventions, delivered pre-transplant, in the immediate postoperative period and extending into long-term follow-up, could further increase PA levels. Additionally, addressing the psychosocial determinants of PA, as well as objective measures of energy expenditure, may help refine personalised strategies that address the diverse needs of kidney transplant recipients.

Author Contributions

Emilia Ferrer-López: conceptualization, methodology, investigation, writing – original draft preparation. **Víctor Cantín-Lahoz:** investigation, data curation, writing – reviewing and editing. **Francisco Javier Rubio-Castañeda:** investigation, data curation, writing – reviewing and editing. **Isabel Blázquez-Ornat:** investigation, resources, writing – reviewing and editing. **Isabel Antón-Solanas:** supervision, writing – reviewing and editing. **Fernando Urcola-Pardo:** supervision, writing – reviewing and editing.

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Ethics Statement

This study was approved by the Biomedical Research Ethics Committee of the Autonomous Community of Aragon (approval no. C.P. - C.I. PI20/278) on June 10, 2020.

Consent

Respondents gave written consent for review and signature before starting interviews.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are not publicly available due restrictions imposed by the ethics committee and data collection site but are available from the corresponding author on reasonable request.

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Appendix 1

Cuestionario Internacional de Actividad Física (IPAQ)

Román Viñas et al. 2013

Estamos interesados en saber acerca de la clase de actividad física que la gente hace como parte de su vida diaria. Las preguntas se referirán acerca del tiempo que usted utilizó siendo físicamente activo(a) en los **últimos 7 días.**

Por favor responda cada pregunta aún si usted no se considera una persona activa. Por favor piense en aquellas actividades que usted hace como parte del trabajo, en el jardín y en la casa, para ir de un sitio a otro, y en su tiempo libre de descanso, ejercicio o deporte.

Piense acerca de todas aquellas **actividades vigorosas** que usted realizó en los últimos 7 días. Actividades vigorosas son las que requieren un esfuerzo físico fuerte y le hacen respirar mucho más fuerte que lo normal. Piense solamente en esas actividades que usted hizo por lo menos **10 minutos continuos**.

1. Durante los últimos 7 días, ¿Cuántos días realizó usted actividades físicas vigorosas como levantar objetos pesados, excavar, aeróbicos, o pedalear rápido en bicicleta?

   _____ días por semana

   Ninguna actividad física vigorosa Pase a la pregunta 3

2. ¿Cuánto tiempo en total usualmente le tomó realizar actividades físicas vigorosas en uno de esos días que las realizó?

_____ horas por día _____ minutos por día

No sabe/No está seguro(a)

Piense acerca de todas aquellas **actividades moderadas** que usted realizo en los **últimos 7 días.** Actividades moderadas son aquellas que requieren un *esfuerzo físico moderado y le hace respirar algo más fuerte que lo normal*. Piense **solamente** en esas actividades que usted hizo por lo menos 10 minutos continuos.

3. Durante **los últimos 7 días**, ¿Cuántos días hizo usted actividades físicas **moderadas** tal como cargar objetos livianos, pedalear en bicicleta a paso regular, o jugar dobles de tenis, rastrillar, limpiar cristales/baldosas? No incluya caminatas.

_____ días por semana

Ninguna actvidad física moderada **Pase a la pregunta 5**

4. Usualmente, ¿Cuánto tiempo dedica usted en uno de esos días haciendo actividades físicas **moderadas**?

_____ horas por día

_____ minutos por día

No sabe/No está seguro(a)

Piense acerca del tiempo que usted dedicó a **caminar** en los **últimos 7 días.** Esto incluye trabajo en la casa, caminatas para ir de un sitio a otro, o cualquier otra caminata que usted hizo únicamente por recreación, deporte, ejercicio, o placer.

5. Durante los **últimos 7 días**, ¿Cuántos días caminó usted por al menos 10 minutos continuos?

   _____ días por semana

   No caminó ***Pase a la pregunta 7***

6. Usualmente, ¿Cuánto tiempo gastó usted en uno de esos días **caminando?**

_____ horas por día

_____ minutos por día

No sabe/No está seguro(a)

La última pregunta se refiere al tiempo que usted **permanenció sentado(a)** en la semana en los **últimos 7 días**. Incluya el tiempo sentado (a) en el trabajo, la casa, estudiando, y en su tiempo libre. Esto puede incluír tiempo sentado(a) en un escritorio, visitando amigos(as), leyendo o permanecer sentado(a) o acostado(a) mirando television.

7. Durante los **últimos 7 días**, ¿Cuánto tiempo permaneció **sentado(a)** en un **día en la semana?**

_____ horas por día

_____ minutos por día

No sabe/No está seguro(a)

Este es el final del cuestionario, gracias por su participación.

Appendix 2

Cuestionario Internacional de Actividad Física (IPAQ-E)

Rubio Castañeda et al. 2017

Estamos interesados en saber la clase de actividad física que la gente hace como parte de su vida diaria. Las preguntas se referirán acerca del tiempo que usted utilizó estando físicamente activo(a) en los **últimos 7 días**.

Por favor responda cada pregunta, aunque usted no se considere una persona activa. Por favor piense en aquellas actividades que usted hace como parte del trabajo, en el jardín y en la casa, para ir de un sitio a otro, y en su tiempo libre de descanso, ejercicio o deporte.

Esta pregunta se refiere al tiempo que usted permaneció **sentado(a)** en una

semana en los **últimos 7 días**. Incluya el tiempo sentado(a) en el trabajo, en casa, estudiando, y en su tiempo libre. Esto puede incluir tiempo sentado(a) en un escritorio, visitando amigos(as), leyendo o permanecer sentado(a) o tumbado(a) mirando la televisión.

1. Durante los **últimos 7 días**, ¿Cuánto tiempo permaneció **sentado(a)** en un **día en la semana**?

_____ horas por día

_____ minutos por día

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No sabe/No está seguro(a)

Piense acerca del tiempo que usted dedicó a caminar en los **últimos 7 días**. Esto incluye trabajo en la casa, caminatas para ir de un sitio a otro, o cualquier otra caminata que usted hizo únicamente por deporte, ejercicio, o placer.

2. Durante los **últimos 7 días**, ¿Cuántos días caminó usted al menos 10

minutos seguidos?

_____ **días por semana**

No caminó ***Pase a la pregunta 4***

3. Usualmente, ¿Cuánto tiempo pasó usted en uno de esos días **caminando**?

_____ **horas por día**

_____ **minutos por día**

No sabe/No está seguro(a)

Piense acerca de todas aquellas actividades **moderadas** que usted realizo en los **últimos 7 días.** Actividades **moderadas** son aquellas que requieren un esfuerzo físico moderado y le hace respirar algo más fuerte que lo normal. Piense *solamente* en esas actividades que usted hizo por lo menos 10 minutos seguidos.

4. Durante los **últimos 7 días**, ¿Cuántos días hizo usted actividades físicas **moderadas** tal como cargar objetos livianos, pedalear en bicicleta a paso regular, o jugar dobles de tenis, rastrillar, limpiar cristales/baldosas? No incluya caminatas.

_____ **días por semana**

Ninguna actvidad física moderada ***Pase a la pregunta 5***

5. Usualmente, ¿Cuánto tiempo dedica usted en uno de esos días haciendo

actividades físicas **moderadas**?

_____ **horas por día**

_____ **minutos por día**

No sabe/No está seguro(a)

Piense acerca de todas aquellas actividades **vigorosas** que usted realizó en los **últimos 7 días**. Actividades **vigorosas** son las que requieren un esfuerzo físico fuerte y le hacen respirar mucho más fuerte que lo normal. Piense *solamente* en esas actividades que usted hizo por lo menos 10 minutos continuos.

6. Durante los **últimos 7 días**, ¿Cuántos días realizó usted actividades físicas **vigorosas** como levantar objetos pesados, excavar cavar en el huerto, aeróbicos, o pedalear rápido en bicicleta?

_____ **días por semana**

Ninguna actividad física vigorosa ***Pase a la pregunta 3***

7. ¿Cuánto tiempo en total usualmente le tomó realizar actividades físicas **vigorosas** en uno de esos días que las realizó?

_____ **horas por día**

_____ **minutos por día**

_____ No sabe/No está seguro(a)

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