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ORIGINAL ARTICLE

Prevalence and correlates of physical activity across kidney disease stages: an observational multicentre study

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ABSTRACT

Background. People with chronic kidney disease (CKD) report high levels of physical inactivity, a major modifiable risk factor for morbidity and mortality. Understanding the biological, psychosocial and demographic causes of physical activity behaviour is essential for the development and improvement of potential health interventions and promotional initiatives. This study investigated the prevalence of physical inactivity and determined individual correlates of this behaviour in a large sample of patients across the spectrum of kidney disease.

Methods. A total of 5656 people across all stages of CKD (1–2, 3, 4–5, haemodialysis, peritoneal dialysis and renal transplant recipients) were recruited from 17 sites in England from July 2012 to October 2018. Physical activity was evaluated using the General Practice Physical Activity Questionnaire. Self-reported cardiorespiratory fitness, self-efficacy and stage of change were also assessed. Binominal generalized linear mutually adjusted models were conducted to explore the associations between physical activity and correlate variables. This cross-sectional observational multi-centre study was registered retrospectively as ISRCTN87066351 (October 2015).

Results. The prevalence of physical activity (6–34%) was low and worsened with disease progression. Being older, female and having a greater number of comorbidities were associated with greater odds of being physically inactive. Higher haemoglobin, cardiorespiratory fitness and self-efficacy levels were associated with increased odds of being active. Neither ethnicity nor smoking history had any effect on physical activity.

Conclusions. Levels of physical inactivity are high across all stages of CKD. The identification of stage-specific correlates of physical activity may help to prioritize factors in target groups of kidney patients and improve the development and improvement of public health interventions.

Keywords: kidney disease, observational, physical activity, self-efficacy

INTRODUCTION

Chronic kidney disease (CKD) is a serious public health issue affecting approximately 6–8% of the UK population, with global estimates between ∼8% and 16% [1]. Along with poor physical functioning and quality of life (QoL), CKD is associated with cardiovascular and metabolic morbidity and mortality risk, placing a considerable strain on national health and social care resources [1, 2].

Physical inactivity, a physical activity level insufficient to meet present recommendations, is the fourth leading cause of death worldwide [3] and costs the UK approximately £7.4–8.3 billion a year, including £1.1 billion to the National Health Service alone [4, 5]. The association between physical inactivity and poor outcomes is well-established for people with CKD, those on dialysis and in kidney transplant recipients (RTRs) [6–9]. People with kidney disease typically engage in a lower level of physical activity than the general population [7, 9–11], resulting in reduced neuromuscular, cardiorespiratory and physical functioning [7], and QoL [6]. Increasing physical activity levels may confer diverse physical and psychological health benefits including moderation of long-term risks of glomerulosclerosis and progressive kidney dysfunction [12].

With the vast majority of physical activity research in kidney populations undertaken in the USA and Western Europe, there remains a lack of research exploring physical activity prevalence in a UK population. The only previous UK study, conducted by Hayhurst and Ahmed [2], showed no difference in physical activity levels across disease stages [CKD, haemodialysis (HD), peritoneal dialysis (PD) and transplant patients]. While seemingly conflicting the wealth of previous research, this finding is likely explained by the use of a 'self-created' un-validated composite physical activity score and a sample of just 100 participants.

Understanding the causes of physical activity behaviour is essential for the development and improvement of potential health interventions and promotional initiatives [13]. Correlates of physical activity have been studied across populations with comprehensive reviews highlighting the role of biological, psychosocial, demographic and interpersonal factors [13–17]. However, limited evidence is available for kidney disease, particularly in the UK.

To improve understanding of physical activity behaviour in kidney patients, the objectives of this study were to: (i) identify the prevalence of physical inactivity and (ii) determine individual correlates of this behaviour in a large sample of patients across the spectrum of kidney disease.

MATERIALS AND METHODS

This cross-sectional observational multicentre study was registered retrospectively as ISRCTN87066351 (October 2015). Data were gathered between July 2012 and October 2018 from 17 sites across England, UK (Supplementary data, Figure S1). Ethical approval was granted by the East Midlands-Leicester South Research Ethics Committee and Health Research Authority (reference: 12/EM/0184). All participants provided written informed consent. This study was performed in compliance with the Declaration of Helsinki.

Participants

Adults (aged ≥18 years) with CKD able to give informed consent were eligible for inclusion. Individuals were stratified into the following cohorts: CKD Stages 1 and 2; CKD Stage 3; CKD Stages 4 and 5; prevalent (>3 months) HD; PD; and RTRs according to the Kidney Disease: Improving Global Outcomes definitions [18]. Those recently transplanted (i.e. <12 weeks) were excluded as post-operative factors are likely to affect physical activity. Patients were recruited from the waiting areas of hospital outpatient clinics or dialysis treatment units. Patients were also identified from local general practitioner (GP) practices.

Outcome measures

All outcome measures were contained in a single survey pack. Patients completed the survey pack either in the waiting areas of outpatient clinics or dialysis treatment units. Those identified by GP practices were sent the survey in the post to be completed at home.

General practice physical activity questionnaire. Physical activity was assessed using the general practice physical activity questionnaire (GPPAQ), a short questionnaire developed by the Department of Health and recommended by The National Institute for Health and Care Excellence and the Kidney Quality Improvement Partnership. The GPPAQ categorizes an individual's current physical activity as: 'active'; 'moderately active'; 'moderately inactive'; or 'inactive' [19, 20]. Anyone scoring less than 'active' was assumed not to be meeting physical activity guidelines [20], i.e. 'insufficiently active'. Types of activities undertaken and self-reported walking pace are also recorded.

Retired and non-working respondents who do not do a sport or cycle cannot be classed as 'active' in the GPPAQ. With potential limitations in a kidney population, questionnaires were re-coded, as per Ahmad *et al.* [20], to include walking in the scoring, i.e. participants who reported walking at a brisk or fast pace for ≥3 h/week were re-coded as 'active'.

Duke activity status index. Physical function was measured by the Duke activity status index, a 12-item questionnaire used to assess activities of daily living [21]. Total scores range from 0 to 58.2 with higher scores denoting greater physical capability. For better interpretation, scores were transformed into estimated peak oxygen uptake (VO_2 peak) values—a marker of cardiorespiratory fitness—as validated in CKD [22].

Stages of change questionnaire. The stages of change questionnaire identifies respondents' state of readiness to adopt a more active lifestyle according to the Stages of Change Model, which consists of five items and forms part of a broader conceptual framework known as the Transtheoretical Model [23]. The stages are: (i) pre-contemplation (no intention to engage in exercise behaviour); (ii) contemplation (may have intentions to exercise in the future); (iii) preparation (has started to perform limited irregular amounts of exercise); (iv) action (meeting activity guidelines); and (v) maintenance (meeting guidelines for >6 months).

Exercise Self-efficacy Questionnaire. The Self-Efficacy Questionnaire (SEQ) was used to assess the individual's confidence to regulate their exercise behaviour in the face of potential barriers representing constructs of negative affect, resisting relapse and making time for exercise [24]. Self-efficacy was rated on a 5-point Likert scale with '1' indicating 'not confident at all' to '5' indicating 'very confident'. The mean score was used as a measure of self-efficacy. The SEQ is used in other chronic disease populations with good reliability and internal consistency [24].

Clinical, comorbidity and demographic data. Clinical [haemoglobin (Hb) and estimated glomerular filtration rate (eGFR)] and demographic (sex, age, smoking status and ethnicity) data were taken from recent medical records and self-reported responses. Kidney function was determined by eGFR using the Modification of Diet in Renal Disease formula. Comorbidities were recorded based on a composite of patient self-report and medical notes. For RTRs, months since transplant and donor type were recorded.

Statistical analysis

Descriptive and frequency statistics were used to describe patient characteristics. Dichotomous and categorical variables are presented as percentages, and continuous variables as median [interquartile range (IQR)] for non-normally distributed data. Participants without completed survey packs were excluded from the analysis and missing data for other variables were analysed listwise. No data imputations were performed. Missing data frequency can be found in Supplementary data, Table S1. All statistical analyses were performed using IBM SPSS version 24 (IBM, USA). Statistical significance was accepted as a $P < 0.05$.

A multinomial generalized linear model was used to explore differences in physical activity status across disease stages with CKD Stages 1 and 2 used as a reference group adjusting for age and sex. Binominal generalized linear mutually adjusted models were conducted to explore the associations between physical activity (coded as a dichotomous variable) and demographics (age, sex, ethnicity and smoking status), clinical parameters (Hb), total number of comorbidities (in addition to kidney disease), VO_2 peak, self-efficacy and stages of change. Stages of change were coded as non-receptive (pre-contemplation) or receptive (contemplation, preparation, action and maintenance). Age, Hb, the total number of comorbidities and VO_2 peak were defined as continuous variables. Self-efficacy scores were treated as a continuous value as per the original citation [24]. Interaction analyses were conducted to assess whether disease stage modified these associations. Significant disease stage interactions were further investigated through stratified analysis with age and VO_2 peak coded as a dichotomous variables based on the median of the total sample. Unless stated, results are expressed as mutually adjusted odds ratio (OR) and 95% confidence intervals (CIs). An OR of >1 indicates a greater odds of being classified as physically 'inactive'. An OR <1 represents a smaller odds of being classified as physically 'inactive'. For continuous variables, odds are reported per 1 unit change.

Availability of data and materials

The datasets used and/or analysed during this study are available from the corresponding author on reasonable request.

RESULTS

Participant characteristics

A total of 5656 people were recruited from 17 sites in England. Data from 398 cases were excluded (no eGFR recorded, $n = 380$; no data recorded, $n = 13$; unreliable data, $n = 5$), leaving a total of 5258 cases for analysis. Information on recruiting centres is included in Supplementary data, Table S1. Full clinical and demographic characteristics are shown in Table 1. Females represented 42% of the total sample. People with CKD Stages 1 and 2 were younger, with the oldest participants found in CKD Stages 4 and 5. Twenty three percent of the sample was from a non-White background. In RTRs, the median (IQR) time post-transplant was 41.0 months (105.0). The majority (66%) of transplants were from cadaveric donation, followed by unrelated living (21%) and related living donation (13%).

Physical inactivity prevalence

The prevalence of insufficient physical activity was high and worsened with disease progression (Figure 1). Patients in CKD Stages 1 and 2 were most active (34% sufficiently active). Physical activity decreased from CKD Stage 3 (17% active) through to CKD Stages 4 and 5 (11% active) before reaching a nadir in people requiring dialysis (only 6% of HD and 8% of PD patients were active). Physical activity of patients in CKD Stages 4 and 5, HD and PD were significantly different ($P < 0.001$) from CKD Stages 1 and 2. Twenty-seven percent of RTRs were sufficiently active.

The frequency of physical activities is reported in Figure 2. Walking was the most popular form of activity across all stages. Full physical activity data can be found in Supplementary data, Table S2.

Correlates of physical inactivity

Table 2 shows the association of demographic, clinical, physical and psychological characteristics with the likelihood of being physically inactive in the combined study cohort. Being older, female and having a greater number of comorbidities were associated with greater odds of being inactive. Higher Hb and VO_2 peak levels were associated with reduced odds of being inactive. Patients in a receptive stage of change and with higher levels of self-efficacy had greater odds of being active. Neither ethnicity nor smoking history had any effect on physical activity.

Interaction analysis revealed that disease stage modified some of these associations, as outlined in Table 2. The direction of the interactions is displayed in Figure 3 (Supplementary data, Table S3). The effect of age was most pronounced in CKD Stages 4 and 5; those >61 years were 5.5 times more likely to be inactive than those ≤61 years. Although females were less active than males across all disease stages, in those on HD, females were 5.0 times more likely to be inactive than males. VO_2 peak levels had a greater effect on activity level in those on dialysis and RTRs; in these groups patients with a VO_2 peak ≤22.3 mL/kg/min were between 4.9 and 18.4 times more likely to be inactive than those with a VO_2 peak >22.3 mL/kg/min.

DISCUSSION

With more than 5000 participants, we present the largest analysis of physical activity behaviour in a UK kidney population. The key findings are: (i) physical inactivity is highly prevalent across all stages of CKD; (ii) physical activity levels worsen with disease progression; (iii) physical activity levels are improved in those with a kidney transplant; and (iv) being older, female, having a lower Hb, lower self-efficacy, lower cardiorespiratory fitness and being in a 'non-receptive' stage of change are associated with being inactive.

Despite the growing evidence supporting the importance of physical activity in kidney disease [6, 7], inactivity was highly prevalent across all stages of CKD. In support of previous literature [9], we observed a decline in physical activity with kidney disease progression, reaching a nadir in those on dialysis. In the UK general population, physical activity data using the GPPAQ are limited, and data concerning adherence to recommended levels of physical activity is variable; however, it is estimated that approximately 35–43% of adults are 'inactive' [4, 19]. In our sample, with the exception of those with CKD Stages 1 and 2 and RTRs (42–46% inactive), physical inactivity was considerably higher in people with more advanced disease. In CKD Stages 4 and 5 and those on dialysis, the prevalence of people defined as 'active' was only 6–11%; this is less than a cohort of 114 mixed cancer (bowel, breast or prostate) patients using the GPPAQ [25].

Table 1. Patient demographic and clinical characteristics

Disease stage $N = 5258$	CKD Stages 1 and 2 $n = 281$	CKD Stage 3 $n = 752$	CKD Stages 4 and 5 $n = 646$	HD $n = 1155$	PD $n = 184$	RTRs $n = 2240$
Sex						
Male, *n* (%)	137 (49)	363 (49)	376 (58)	726 (64)	122 (67)	1289 (59)
Female, *n* (%)	144 (51)	383 (51)	270 (42)	405 (36)	61 (33)	909 (41)
Age, years						
Median (IQR)	47.0 (26.0)	72.0 (18.0)	73.0 (21)	65.0 (21.0)	64.0 (22.0)	53.0 (20.0)
≤61 years, *n* (%)[a]	212 (76)	179 (24)	176 (27	469 (42)	78 (43	1532 (71)
>61 years, *n* (%)	68 (24)	559 (76)	468 (73)	656 (58)	104 (57)	636 (29)
Ethnicity						
White British, *n* (%)	208 (83)	413 (89)	508 (79)	419 (49)	103 (66)	1503 (74)
White other, *n* (%)	7 (3)	18 (4)	14 (2)	27 (3)	6 (4)	143 (7)
Indian, *n* (%)	17 (7)	19 (2)	37 (6)	114 (13)	14 (9)	39 (2)
Pakistani, *n* (%)	0 (0)	2 (0)	3 (1)	25 (3)	6 (4)	19 (1)
Asian other, *n* (%)	4 (2)	8 (2)	7 (1)	39 (5)	8 (5)	136 (7)
Caribbean, *n* (%)	5 (2)	3 (1)	2 (0)	90 (11)	9 (6)	69 (3)
African, *n* (%)	2 (1)	0 (0)	7 (1)	96 (11)	7 (4)	30 (1)
Other, *n* (%)	7 (3)	2 (0)	5 (1)	42 (5)	3 (2)	93 (5)
Smoking status						
Current smoker, *n* (%)	47 (17)	65 (9)	68 (11)	107 (10)	13 (7)	161 (7)
Never smoked, *n* (%)	122 (45)	324 (45)	256 (41)	556 (50)	88 (49)	1262 (58)
Previous smoker, *n* (%)	105 (38)	334 (46)	295 (48)	453 (41)	80 (44)	736 (34)
eGFR, median (IQR), mL/min/1.73 m^2	78.0 (23.0)	44.0 (15.0)	20.2 (10.0)	6.5 (4.0)	7.0 (5.0)	46.0 (26)
Hb, median (IQR), g/dL	13.4 (2.4)	12.7 (2.3)	11.6 (2.1)	11.2 (1.8)	10.9 (2.2)	12.7 (2.5)
Diabetes, *n* (%)	33 (12)	187 (26)	217 (35)	341 (39)	50 (34)	374 (22)
CVD, *n* (%)	20 (7)	182 (25)	146 (24)	201 (23)	25 (17)	175 (10)
Hypertension, *n* (%)	119 (47)	292 (71)	481 (79)	563 (64)	91 (62)	1275 (73)
Total no. of comorbidities[b]						
Mean (SD)	1.1 (1.1)	1.8 (1.3)	1.9 (1.3)	1.0 (1.0)	1.2 (1.1)	1.4 (1.1)
Median (IQR)	1.0 (2.0)	2.0 (2.0)	2.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (1.0)
DASI						
Median (IQR)	31.5 (32.4)	31.7 (31.8)	26.0 (31.3)	18.0 (20.5)	23.2 (24.0)	38.2 (32.4)
VO_2 peak (mL/kg/min)						
Median (IQR)	23.1 (13.9)	23.2 (13.7)	20.8 (13.4)	17.3 (8.8)	19.6 (10.3)	26.0 (13.9)
≤22.3 mL/kg/min, *n* (%)[c]	123 (44)	351 (47)	363 (56)	818 (74)	120 (66)	750 (37)
>22.3 mL/kg/min, *n* (%)	158 (56)	400 (53)	283 (44)	289 (26)	63 (34)	1278 (63)
Stage of change						
Pre-contemplation, *n* (%)	42 (15)	261 (37)	291 (47)	460 (44)	67 (38)	335 (18)
Contemplation, *n* (%)	63 (23)	111 (16)	108 (18)	215 (20)	44 (25)	436 (23)
Preparation, *n* (%)	58 (21)	118 (17)	105 (17)	202 (19)	34 (19)	465 (25)
Action, *n* (%)	21 (8)	30 (4)	19 (3)	47 (4)	7 (4)	157 (8)
Maintenance, *n* (%)	89 (33)	195 (27)	94 (15)	129 (12)	23 (13)	471 (25)
Exercise SEQ						
Median (IQR)/5	3.0 (1.5)	2.2 (2.2)	2.2 (2.0)	1.2 (1.6)	1.6 (1.7)	2.4 (2.0)

Data shown as frequencies or median (IQR), unless otherwise stated. DASI = Duke Activity Status Index; [a]61 years denotes median of total sample; [b]total no. of additional comorbidities (excluding kidney disease); [c]22.3 mL/kg/min denotes median of total sample. Percentage of missing excluded from percentage accumulation of other variables.

It is perhaps unsurprising that physical activity levels worsen as CKD progresses given the increasing symptom burden [26] and reductions in physical function aggravated by anaemia, metabolic acidosis, inflammation and malnutrition [9]. People with CKD Stages 1 and 2 generally have less disease burden and are treated in primary care by a GP without the need for specialist referral. In our study, this group of 'early' CKD patients was younger with a lower prevalence of additional comorbidities.

Physical activity was lowest in patients requiring dialysis, with 94% of HD patients and 92% of PD patients 'insufficiently active'. Low physical activity in dialysis patients is well-described [8–11, 27–29] with several causes including uraemia, fatigue, comorbidity burden, anaemia and depression [30, 31]. In HD patients, post-dialysis fatigue as well the logistical processes of dialysing several days per week negatively impact physical activity [32]. Patients on PD may feel discouraged from participating in physical activity due to concerns about the development of hernias and leaks, or uncertainty surrounding appropriate exercise regimens [28]. Accordingly, such levels of inactivity are worrying given the association with mortality in HD and PD [33].

Physical activity was higher in transplant patients relative to those with advanced CKD. Such 'recovery' of physical activity following a transplant has been previously observed [34–36]. Nielens *et al.* [37] reported an immediate decrease in physical activity 1-month post-transplant, followed by increased physical activity and a plateau after 1 year. All RTRs in this study were >12-weeks post-transplant, thus negating any initial decline. Nonetheless, relatively few met national recommendations. Although receipt of a kidney transplant has been shown to improve QoL and reduce the risk of end-stage kidney disease (ESKD)-related outcomes [38], new (e.g. fear of harming graft

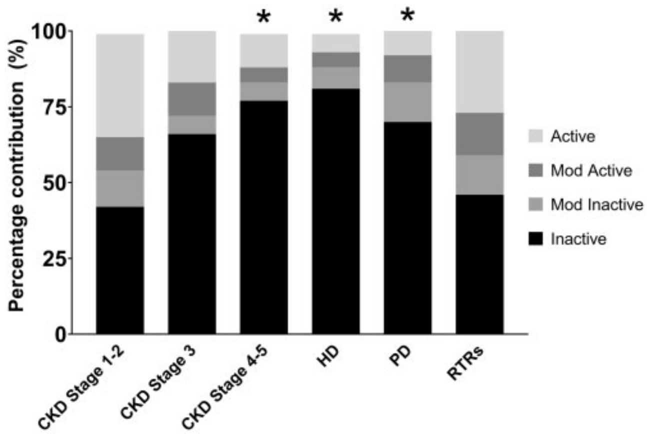

FIGURE 1: Levels of physical activity status across disease stages. Physical activity status is taken from the GPPAQ adjusted to include ≥3 h of walking as 'active' (GPPAQ-WALK). Significant differences versus CKD Stages 1 and 2 (reference group) denoted by asterisks and set at $P < 0.001$; analysis adjusted for age and sex.

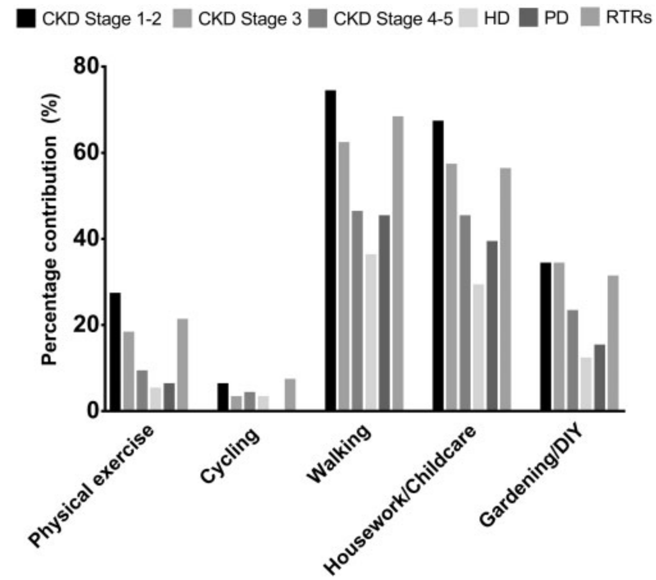

FIGURE 2: Frequency of physical activities reported. Physical activity status is taken from GPPAQ. DIY = 'do-it-yourself', e.g. maintenance or repair work.

and immunosuppression-related side effects) and existing pre-transplant (e.g. fatigue and low physical condition) barriers remain [36, 39, 40]. The low rates of physical activity in RTRs observed are of concern because, along with improved physical and psychological QoL, greater physical activity is associated with improved graft function [6, 9, 34–36].

It is well-recognized in epidemiological research that increasing age is associated with reduced physical activity [13–17]. We observed an inverse relationship between age and physical activity across all stages, although this was particularly evident in CKD Stages 4 and 5. Likely age-related factors include declines in health status, mobility or motivation [16], intensified by reductions in physical and kidney function. Consistent with research in both large general [13–17] and kidney population studies [29], sex emerged as a strong correlate of physical activity. In people with non-dialysis CKD, males were approximately three times more likely to be active than females, and in those undergoing HD, males were over five times more likely to be active. Multiple explanations like family and societal roles, psychological issues and living conditions may account for these differences [15].

Regardless of CKD stage, the physical function and cardiorespiratory fitness of our sample were poor. We observed that a higher VO_2 peak was associated with a greater likelihood of being active in patients with ESKD (PD and HD) and RTRs. While this relationship is likely bi-directional, having sufficient cardiorespiratory fitness is an important criterion of the capability to be active [39], and low cardiorespiratory fitness is associated with impaired physical functioning [9]. Segura-Ortí *et al.* [27] found that poor physical function was associated with reduced physical activity in HD patients [41], and RTRs' [36] physical activity has been closely associated with physical function. Importantly, while impaired fitness may hinder patients from undertaking physical activity, being inactive contributes to further reductions in physical capability [9]. Interestingly, our analysis suggests that physical fitness may not be an important factor in determining physical activity in those with non-dialysis-dependent CKD.

The concentration of oxygen-carrying Hb is a well-established limiting parameter of cardiorespiratory capacity. With anaemia a common complication of CKD, it is unsurprising that low Hb levels have been associated with inactivity [9]. We found higher Hb levels were associated with greater odds of being active regardless of the CKD stage. This supports previous research [2, 27, 30] although it contrasts others [2, 42].

From a psychological perspective, self-efficacy is purportedly the most important predictor of engaging in long-term maintenance of physical activity [14, 43]. Self-efficacy refers to an individual's beliefs about their capability to perform a particular behaviour [44], and in our cohort, the confidence to regulate exercise behaviour in the face of potential barriers. We found higher self-efficacy was associated with greater odds of being active across all CKD groups. Previous studies in kidney populations are limited; however, studies in RTRs [9, 35, 39, 40], those on dialysis [45, 46] and unspecified kidney disease [47] have shown associations between self-efficacy and physical activity. With growing evidence underlining its importance, strategies to promote self-efficacy may increase physical activity engagement [9, 35, 39, 47].

Patients in a 'receptive' stage of change were more likely to be active. The Stages of Change model from Prochaska and DiClemente's Transtheoretical Model has been used extensively to study health-related behaviours including physical activity [48]. The model postulates that individuals engaging in a new behaviour move through non-receptive to receptive stages [24]. For those in a non-receptive stage, the will to abstain from physical activity is greater than the self-efficacy for it [48]. In these people, traditional interventions are unsuitable and targeting of stage-specific interventions is required [24, 48]. Physical activity promotion should focus on 'building readiness' to change and people may benefit most from informational, educational and motivational experiences designed to increase the appeal and expectations of physical activity [24, 48].

Table 2. Correlates of physical inactivity and interactions with disease group

Odds ratio statistics $N = 2956$	OR (95% CI)	Main effect, P-value	Interaction, P-value
Age	1.029 (1.021–1.037)	<0.001*	0.001*
Sex [male (reference)]	1	<0.001*	0.03*
Female	1.668 (1.340–2.076)		
Ethnicity [White British (reference)]	1	0.13	0.71
Non-white	1.270 (0.930–1.733)		
Hb	0.932 (0.879–0.989)	0.02*	0.24
Smoking status [never smoked (reference)]	1	0.91	0.85
Current smoker	1.058 (0.738–1.517)		
Previous smoker	0.974 (0.779–1.219)		
Total comorbidities[a]	1.172 (1.057–1.300)	0.003*	0.37
Stage of change [non-receptive (reference)]	1	<0.001*	0.29
Receptive	0.352 (0.247–0.501)		
SEQ	0.703 (0.642–0.770)	<0.001*	0.34
VO_2 peak	0.923 (0.909–0.937)	<0.001*	<0.001*

Data displayed as mutually adjusted OR with 95% CI for main effects; an OR of >1 indicates greater odds of being classified as physically 'inactive'. Significant interaction denotes modifying effect of CKD group. The direction of the significant interactions for age, sex and VO_2 peak is displayed in Figure 3. Significance denoted by asterisk and set at $P < 0.05$.
[a]Total no. of additional comorbidities (excluding kidney disease).

Despite its large and diverse sample, our study is limited by its cross-sectional design, a common limitation in physical activity literature [17] precluding determination of causality. Nonetheless, this design can provide evidence about potential mediators for the planning of interventions and may help prioritize factors in target groups of kidney patients. Such design also allows several variables to be assessed at low cost, providing evidence for intervention design improvement [49]. The use of self-report is widely used for physical activity assessment, despite various shortcomings (e.g. recall bias and misinterpretation) [8]. In this study, the GPPAQ was used to measure physical activity. While easy to administer, research has revealed a sensitivity between 19% and 46% and specificity of 50–85% (classed as 'active') compared with accelerometery [20, 50]. It is important to note that our population consisted of patients willing to engage in the research study and return a completed survey. Such sampling bias may be evident in somewhat lower prevalence of comorbidities such as hypertension, diabetes and cardiovascular disease (CVD); this may reduce the generalizability of our findings to a wider patient population.

The solution to combating physical inactivity is complex, multifaceted and likely dependent on each individual. Our results show strategies promoting self-efficacy may be key to increasing physical activity. Self-efficacy arises from four primary sources: mastery experiences, social modelling, social persuasion and the interpretation of physiological and emotional responses [43, 44]. While beyond the scope of this work, each of these can be targeted to maximize physical activity engagement. For example, facilitated by a healthcare professional, the setting of challenging, but reachable, physical activity goals can be an effective method of ensuring regular successful experience. Social or group activities may aid in social modelling and persuasion, and being able to interpret aches and pains associated with activity after a considerable period of time as positive responses enhance self-efficacy [43]. With only small increases in activity being beneficial, nephrologists and healthcare professionals should engage and discuss the risks and benefits of physical activity with their patients, identify barriers and highlight its relative safety and the adverse outcomes associated with inactivity. Although proper infrastructure and specialist supervision to facilitate exercise programmes for CKD patients are largely lacking, a simple prescription of short-term home-based aerobic exercise at moderate intensity, such as brisk walking or cycling for 30–60 min at least three times per week may form the basis of a cheap and safe programme. Structured exercise incorporating strength and balance training may be introduced in appropriate patients [9].

In conclusion, in the largest UK cohort of its kind, we established that physical inactivity is highly prevalent across all stages of kidney disease, reaching a nadir in those requiring dialysis. We were able to identify stage-specific correlates of physical activity. Our findings are important as physical inactivity is a major modifiable risk factor for morbidity and mortality, and a better understanding of the causes of physical activity behaviour is essential for the development and improvement of public health interventions.

SUPPLEMENTARY DATA

Supplementary data are available at ndt online.

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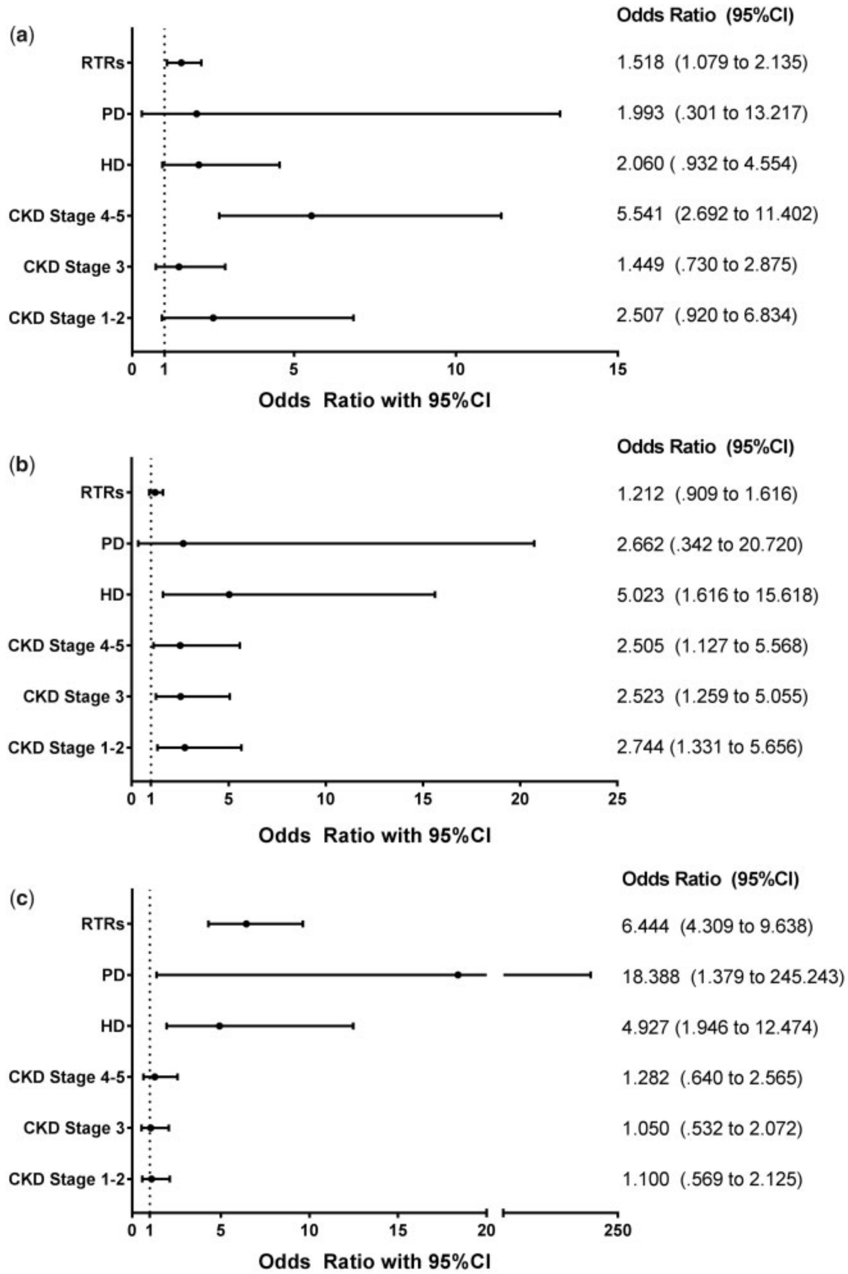

FIGURE 3: Physical inactivity and significant disease group interactions. (**A**) Age ≤61 years (median) as reference, (**B**) sex (male as reference) and (**C**) VO_2 peak [>22.3 mL/kg/min (median) as reference]. Data displayed as mutually adjusted OR with 95% CI; an OR of >1 indicates greater odds of being classified as physically 'inactive' compared with the reference. Age and VO_2 peak are coded as a dichotomous variables based on the median of the total sample population.

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AUTHORS' CONTRIBUTIONS

A.C.S. and J.O.B. contributed to the research idea and study design. T.J.W., A.L.C., D.G.D.N., K.L.H. and Y.S. contributed to the generation/collection of data. T.J.W., A.L.C., D.G.D.N., K.L.H., Y.S., J.O.B., T.Y. and A.C.S. helped in data analysis/interpretation. T.J.W. and T.Y. performed the statistical analysis. A.C.S., T.Y. and J.O.B. were involved in supervision or mentorship. T.J.W. drafted the manuscript. Each author contributed important intellectual content during manuscript revision and accepts responsibility for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests. T.Y. reports grants from National Institute for Health Research during the conduct of the study.

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The Australian Calciphylaxis Registry: reporting clinical features and outcomes of patients with calciphylaxis

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ABSTRACT

Background. Calciphylaxis is a rare disease, predominantly affecting patients with chronic kidney disease (CKD) and associated with significant morbidity and mortality due to progressive cutaneous calcification, necrotic ulceration and infection. Clinical registries have been established to better understand the risk factors, optimal treatments and disease outcomes of calciphylaxis.

Methods. We established a prospective, Internet-based clinical registry for the online notification of calciphylaxis cases in Australia. Seven institutions participated, with data recorded on patient characteristics, biochemical parameters, treatments and disease outcomes.

Results. Between 2014 and 2019, 47 cases of calciphylaxis were registered. The mean patient age was 66 ± 11 years and body mass index was 35 ± 9 kg/m^2, with a higher proportion of females (51%). Eighty-seven percent of patients had end-stage kidney disease (ESKD), with 61% on hemodialysis or hemodiafiltration, with a median dialysis vintage of 4.8 [interquartile range (IQR) 1.7–7.4)] years. Five patients had CKD not requiring dialysis and two were kidney transplant recipients. Diabetes was present in 76% of patients and the cause of ESKD in 60%; 34% received vitamin K antagonists (VKAs) before diagnosis. The median parathyroid hormone level at diagnosis was 32 (IQR 14–50) pmol/L. The most common site of calciphylaxis was the lower limbs (63%), with 19% of patients having more than one area involved. Ten patients (22%) had a resolution of calciphylaxis and 25 died, with 50% mortality at a median of 1.6 (IQR 0.2–2.5) years from diagnosis.

Conclusions. The Australian Calciphylaxis Registry highlights risk factors for calciphylaxis, including diabetes, obesity and VKA use. Resolution of calciphylaxis is uncommon despite multimodal therapy and mortality from calciphylaxis in the first year following diagnosis remains high.

Keywords: calcific uremic arteriolopathy, calciphylaxis, chronic kidney disease, end-stage kidney disease, mineral metabolism

INTRODUCTION

Calciphylaxis is a rare disease predominately affecting patients with chronic kidney disease (CKD), especially those with end-stage kidney disease (ESKD) on dialysis, although it has also been described in patients with normal kidney function and following kidney transplantation [1]. Calciphylaxis presents with painful subcutaneous lesions that can develop into necrotic ulcers. Due to the progressive and unrelenting nature of cutaneous calcification, calciphylaxis is associated with significant