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Physical activity and energy expenditure in haemodialysis patients: an international survey

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Abstract

Background. The assessment of physical activity and energy expenditure is relevant to the care of maintenance haemodialysis (MHD) patients. In the current study, we aimed to evaluate measurements of physical activity and energy expenditure in MHD patients from different centres and countries and explored the predictors of physical activity in these patients.

Methods. In this cross-sectional multicentre study, 134 MHD patients from four countries (France, Switzerland, Sweden and Brazil) were included. The physical activity was evaluated for 5.0 ± 1.4 days (mean ± SD) by a multisensory device (SenseWear Armband) and comprised the assessment of number of steps per day, activity-related energy expenditure (activity-related EE) and physical activity level (PAL).

Results. The number of steps per day, activity-related EE and PAL from the MHD patients were compatible with a sedentary lifestyle. In addition, all parameters were significantly lower in dialysis days when compared to non-dialysis days ($P < 0.001$). The multivariate regression analysis revealed that diabetes and higher body mass index (BMI) predicted a lower PAL and older age and diabetes predicted a reduced number of steps.

Conclusions. The physical activity parameters of MHD patients were compatible with a sedentary lifestyle. This inactivity was worsened by aging, diabetes and higher BMI. Our results indicate that MHD patients should be encouraged by the health care team to increase their physical activity.

Keywords: energy expenditure; haemodialysis; nutrition; physical activity

Introduction

Physical activity is defined as bodily movement produced by the contraction of skeletal muscle that increases energy expenditure [1]. Patients on maintenance haemodialysis (MHD) are exposed to several factors associated with decreased physical activity such as the catabolic disorders that may cause loss of muscle mass and lead to sarcopenia [2] and co-morbidities like diabetes, anaemia, bone and mineral disorders, protein–energy wasting (PEW) and obesity [3–5]. Moreover, as a high proportion of MHD patients are elderly, disorders related to aging can also contribute to diminished physical activity [5, 6].

A variety of methods can be used to evaluate physical activity. Among them are interviews, questionnaires, 7-day activity diaries and body motion sensors, which include pedometers (step counters) and accelerometers (detection of body displacement) [7]. The use of body motion sensors has been increasingly applied to monitor physical activity in healthy individuals and in patients with chronic diseases [7]. In patients with chronic kidney disease (CKD) on MHD, a limited number of studies assessed physical activity by the daily number of steps, physical activity counts and activity-related energy expenditure (activity-related EE) [3–5, 8]. A common finding is the reduced physical activity in MHD patients when compared to healthy individuals [3–5, 8]. Also interesting is the diminished physical activity pattern on dialysis days, possibly due to the time spent seated for the dialysis session [3]. However, as the aforementioned studies were based on relatively small samples of patients ($n = 20–60$) from single centres, a multicentre study with bigger sample comprising patients from different countries would add valuable information regarding this subject.

The importance of studying physical activity in MHD patients lies in the evidence that low physical activity is associated with higher hospitalization and mortality rates [9, 10]. In addition, the measurement of the energy expenditure is important for estimating the energy requirements, a subject scarcely investigated in MHD population. Therefore, our major goals were (i) assessing the physical activity and energy expenditure in a large number of patients on MHD from different centres and countries and (ii) to explore the clinical predictors of physical activity.

Materials and methods

Patients

This is a cross-sectional study including 134 adult patients on MHD, defined by a dialysis vintage of >1 month, from five centres: Aurad-Aquitaine, Bordeaux—France (Centre 1; n = 36); University of Lyon, Hospital E. Herriot, Lyon—France (Centre 2; n = 26); University Hospital, Lausanne—Switzerland (Centre 3; n = 30); Oswaldo Ramos Foundation, São Paulo—Brazil (Centre 4; n = 29); Karolinska University Hospital, Karolinska Institute, Stockholm—Sweden (Centre 5; n = 13). Amputee patients, those >18 years old, and patients hospitalized in the week before the study were excluded. Table 1 shows the main demographic characteristics from all patients from each centre.

The Local Research Ethical Committee from each centre approved this study and all patients provided written informed consent before their inclusion in the study.

Methods

Physical activity and energy expenditure were evaluated by a portable device (SWA) (Armband; Sense Wear PRO_2—Bodymedia®—Pittsburg—PA). The physical activity measurements comprised the assessment of number of steps per day, activity-related EE and physical activity level (PAL). The SWA is a wearable body monitor that enables continuous physiological monitoring. The information content in the equipment is downloaded to a software (InnerView® Professional version 5.0, Bodymedia) to yield measurements number of steps per day and activity-related EE. All participants wore the equipment in the opposite upper arm of the arterial venous fistula for mean of 5.0 ± 1.4 consecutive days, including overnight, with at least 1 day encompassing a dialysis session and 1 day free of dialysis. Patients were instructed to remove the equipment only for bathing or any other water activity. When downloading the data, the software provided the data and the on-body time, which was measured at 1-min intervals. A threshold of 90% on-body time was used for including the patient in the analysis. The equipment provides data on activity-related EE (kcal/day) and number of steps (per day). For each patient, these data were calculated as the average for total days, for dialysis days and for non-dialysis days. After that, these values were averaged for total days (5.0 ± 1.4 days), for dialysis days (1.9 ± 0.7 days) and for non-dialysis days (3.2 ± 0.8 days). To estimate the activity-related EE, the equipment was set to use a threshold of physical activity with an MET (metabolic equivalent) >3.0. The PAL was calculated as the ratio between total energy expenditure (TEE)/basal energy expenditure. TEE was estimated as the sum of basal energy expenditure and activity-related EE divided by 0.9 (providing an estimate of additional energy expenditure for the thermal effect of food, which accounts for ~10% of TEE). Basal energy expenditure was estimated by the Harris and Benedict equation [11].

The validity of the equipment SWA has been tested in two studies comprising non-CKD patients [12, 13]. In both studies, an acceptable degree of agreement was found between doubly labelled water (DLW) technique and SWA.

The indices proposed for classifying pedometer-determined physical activity in healthy adults were used for categorizing the level of physical activity as sedentary (≤4999 number of steps per day); low active (5000–7499 number of steps per day); somewhat active (7500–9999 number of steps per day); active (10 000–12 499 number of steps per day) and highly active (≥12 500 number of steps per day) [14]. In addition, we have also used the classification of lifestyle in relation to the intensity of physical activity proposed by the World Health Organization (WHO): sedentary or light activity lifestyle (PAL: 1.40–1.69), active or moderately active lifestyle (PAL: 1.70–1.99) and vigorous or vigorously lifestyle (PAL: 2.00–2.40) [15].

Anthropometry included dry body weight (taken after the dialysis session) and height. Body mass index (BMI) was calculated as body weight per squared height (kg/m^2). Blood samples were drawn before the dialysis session on a midweek day for the measurement of serum creatinine (Jaffe's method), high sensitive C-reactive protein (CRP) (nephelometry) and serum albumin (assessed by bromocresol green). These measurements were performed in the laboratory of each dialysis unit.

Statistical analysis

The statistical analyses were performed with SPSS® software, version 13.0 (Chicago, IL). Normally distributed variables are shown as mean ± SD, while the skewed ones are shown as median (range). Comparisons among the five centres were performed with chi-square test, one-way analysis of variance or Kruskal–Wallis test, as appropriate. For comparing TEE and physical activity between non-dialysis and dialysis days, pair-matched t-test or Wilcoxon signed-rank test were used for normally and not normally distributed variables, respectively. Spearman linear correlation coefficients were calculated to evaluate associations among variables. A multiple regression analysis (stepwise and forward) was performed to

Table 1. Main demographic and clinical characteristics of haemodialysis patients according to the dialysis centres (N = 134)[a]

	All patients (N = 134)	Centre 1 (n = 36)	Centre 2 (n = 26)	Centre 3 (n = 30)	Centre 4 (n = 29)	Centre 5 (n = 13)	P
Male (n, %)	64 (47.7)	21 (58.3)	8 (30.8)	10 (33.3)	19 (65.5)	6 (46.1)	0.02[b]
DM (n, %)	36 (26.9)	6 (16.7)	11 (42.3)	13 (43.3)	3 (10.3)	3 (23.1)	0.08[b]
Age (years)	54.9 ± 15.9[c]	50.7 ± 14.7	67.1 ± 14.4	60.1 ± 15.0	46.6 ± 12.3	48.6 ± 13.5	<0.001[d] (2, 3 > 1, 4, 5)
Dialysis vintage (months)	29 (1; 360)[e]	30 (1; 216)	29 (5; 192)	30 (3; 360)	30 (5; 128)	12 (4; 48)	0.20[f]
BMI (kg/m^2)	24.4 ± 4.8	24.0 ± 5.4	24.9 ± 4.3	25.6 ± 4.7	24.4 ± 4.4	21.6 ± 4.5	0.15[d]
Albumin (g/L)	40 ± 3.2	39 ± 4.1	39 ± 2.5	41 ± 2.9	40 ± 2.1	37 ± 3.2	0.02[d] (3 > 1, 2, 4 > 5)
S-creatinine (mg/dL)	9.2 ± 3.5	8.8 ± 3.3	7.5 ± 1.9	7.9 ± 3.0	12.9 ± 3.4	8.8 ± 2.8	<0.001[d] (4 > 1, 2, 3, 5)
CRP (mg/L)	3.0 (0.16; 77)	4.5 (1; 77)	4.4 (0.2; 15.9)	2.5 (2; 24)	3 (0.2; 30.5)	2 (0.16; 28.2)	0.07[f]
Haemoglobin (mmol/L)	7.2 ± 0.93	7.0 ± 0.81	6.9 ± 1.43	7.4 ± 0.68	7.6 ± 0.62	6.9 ± 0.74	0.04 (4 > 1, 2, 5)

[a]Centre 1, Bordeaux; Centre 2, Lyon; Centre 3, Lausanne; Centre 4, Sao Paulo; Centre 5, Stockholm; S-creatinine, serum creatinine.
[b]Chi-square test.
[c]Mean ± SD.
[d]ANOVA, one-way analysis of variance.
[e]Median (range).
[f]Kruskal–Wallis test.

evaluate the main determinants of PAL and number of steps per day. Because the number of steps per day had a skewed distribution, it was log transformed (natural base) before including it in the model. The independent determinants tested in this model were those considered clinically significant such as gender, age, diabetes mellitus (DM), BMI, serum creatinine (S-creatinine) and log CRP. A P-value <0.05 was considered of statistical significance.

Results

One hundred and thirty-four patients on MHD from five centres and four countries were studied. The main demographic and clinical characteristics are shown in Table 1. For the whole population, there were an equivalent proportion of genders and 26.9% of the patients were diabetic. The mean age was 54.9 ± 15.9 years and median dialysis vintage was 29 (1; 360) months. The BMI, albumin and CRP values were not indicative of either PEW or inflammation, although the range indicated that some patients were not within the normal values. The patients were dialysed three times a week for ~12 h/week. The main diagnoses were diabetes (n = 31, 23%); glomerulonephritis (n = 20, 15%) and hypertension (n = 18, 13%). Forty patients had other causes of CKD and in 14 patients, the aetiology was not determined.

Among the five centres, there was a predominance of males in Centre 1. Dialysis vintage and BMI were similar among the dialysis centres. Regarding albumin, a significantly higher concentration was observed in Centre 3 in comparison to the other centres. CRP values were comparable among the five centres and the haemoglobin concentration was significantly higher in Centre 4.

Table 2 depicts TEE and the physical activity measurements from all centres analysed together. Measurements of physical activity were lower on dialysis days than on non-dialysis days. In addition, they were indicative of sedentary to low active lifestyle, as shown by the median number of steps <7500/day [14] and by a mean PAL ≤1.4 [15]. When the physical activity was analysed according to the pedometer-determined levels [14] (Figure 1), the majority of the patients (64%) had physical activity indicative of sedentary or low active lifestyle. The activity-related EE was equivalent to 15.3 ± 10.9, 12 ± 10 and 16 ± 12% of the TEE in the total days, in dialysis and non-dialysis days, respectively. In addition, physical activity measurements were reduced regardless of the centre studied (data not shown).

Table 3 shows univariate associations between the physical activity and the main characteristics of the patients. Age and BMI were negatively associated with all physical activity measurements, i.e. older patients and those with higher BMI were more sedentary. S-creatinine was positively associated with almost all physical activity measurements and CRP showed a mild negative association with number of steps and PAL. Dialysis vintage and haemoglobin (data not shown) were not associated with any of the studied measurements.

Tables 4 and 5 describe the main determinants of number of steps per day and PAL, respectively. Age and DM were the main determinants of number of steps per day, while BMI and DM were the determinants of PAL.

Discussion

The present study investigated physical activity measurements and energy expenditure in MHD, a subject of increasing interest in this population. In order to fulfil this aim, a multicentre study was performed, including MHD patients from five centres in four countries. A noteworthy finding is the very low number of steps per day, activity-related EE and PAL observed in MHD patients from different centres and countries under different medication scheme, pattern of food intake and dialysis treatment. Additionally, the physical activity was lower in dialysis days than in non-dialysis days.

Studies addressing physical activity by portable devices are scarce in MHD. Johansen *et al.* [5], by using an accelerometer worn on waking hours, demonstrated that MHD patients were 35% less active than healthy sedentary individuals. Comparable findings were reported by measuring the number of steps in MHD patients and healthy controls

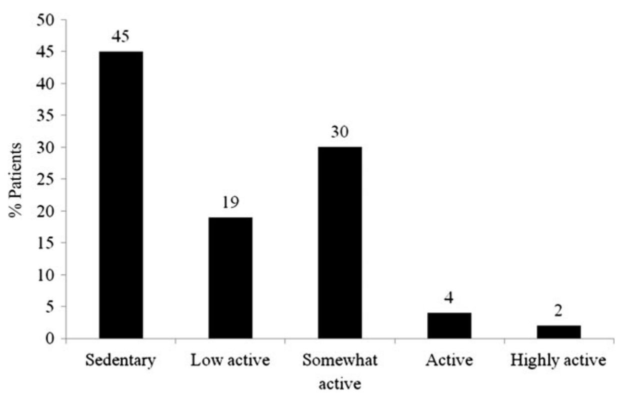

Fig. 1. Percentage of patients in each level of physical activity, determined by step counter. Sedentary ≤4999 number of steps per day; low active: 5000–7499 number of steps per day; somewhat active: 7500–9999 number of steps per day; active 10 000–12 4999 number of steps per day and highly active ≥12 500 number of steps per day [14].

Table 2. Total energy expenditure and physical activity in haemodialysis patients according to dialysis and non-dialysis days (n = 134)

	Total days	Dialysis day	Non-dialysis day	P
TEE (kcal/day)	1938 ± 437	1864 ± 408	1985 ± 484	0.001[a]
Activity-related EE (kcal/day)	289 (0; 1793)	202 (0; 1152)	303 (0; 2113)	0.001[b]
Steps (number/day)	5660 (73; 16 565)	4620 (77; 13 957)	5544 (72; 18 220)	0.001[b]
PAL	1.39 ± 0.2	1.33 ± 0.2	1.42 ± 0.3	0.001[a]

[a]Pair-matched test: dialysis day versus non-dialysis days.
[b]Wilcoxon signed-rank test: dialysis day versus non-dialysis days.

Table 3. Correlation coefficients (r) between physical activity and the main variables studied in haemodialysis patients (n = 134)

	TEE	Activity-related EE	Steps	PAL
Age	−0.51**	−0.34**	−0.49**	−0.27**
Dialysis vintage	−0.08	0.03	−0.12	0.06
BMI	0.20**	−0.20*	−0.21**	−0.28**
S-creatinine	0.37**	0.17‡	0.30**	0.10
Albumin	0.11	0.06	0.09	0.05
CRP	0.04	−0.14	−0.16‡	−0.16‡

**P < 0.001.
*P < 0.05.
‡P = 0.06.

Table 4. Main determinants of number number of steps per day in haemodialysis patients (n = 134; r^2 = 0.30)[a]

	Unstandardized coefficients		Standardized coefficients	
	B	Standard error	β	P
Intercept	9.739	0.223	NA	<0.01
Age	−0.02	0.004	−0.40	<0.01
Diabetes	−0.57	0.143	−0.30	<0.01

[a]Linear multiple regression analysis. Independent variables tested in the model: age, BMI, gender, diabetes (presence), log CRP and serum creatinine. NA: not applicable.

Table 5. Main determinants of PAL in haemodialysis patients (n = 134; r^2 = 0.12)[a]

	Unstandardized coefficients		Standardized coefficients	
	B	Standard error	β	P
Intercept	1.73	0.111	NA	<0.01
BMI	−0.01	0.005	−0.24	<0.01
Diabetes	−0.11	0.047	−0.20	0.02

[a]Linear multiple regression analysis. Independent variables tested in the model: age, BMI, gender, diabetes (presence), log CRP and serum creatinine. NA: not applicable.

[4]. Finally, using a similar technology, a recent study by Baria *et al.* [8] showed that activity-related EE and number of steps per day were, respectively, 46.4 and 28.8% lower in MHD when compared to age- and gender-matched sedentary healthy controls. The latter study comprised by a population of younger MHD patients (45.6 ± 14.1 years) and even then, a lower level of physical activity was found [8]. In the present study, the mean age (54.9 ± 15 years) was lower than the average observed in European countries and in the USA (63.7 ± 14.5 years) [16]. Therefore, if we consider that age is negatively associated with level of physical activity, as shown in this and other studies [5, 6], the majority of MHD patients have an even lower physical activity pattern. This finding is also observed in patients new to dialysis, as revealed by the Comprehensive Dialysis Study, in which the physical activity was below the fifth percentile for healthy individuals for all gender and sex categories [17]. Altogether, these findings indubitably show that MHD patients have a sedentary or an inactive lifestyle. It is noteworthy that the observed activity-related EE was equivalent to 12–16% of the TEE, which is lower than normally expected (15–30%) [15]. Although speculative, this low physical activity might contribute to the lack of appetite [18, 19] and diminished energy intake [20] often observed in MHD patients.

Our study demonstrates that on dialysis days, the physical activity is lower than on non-dialysis days, mainly for activity-related EE and number of steps per day. Our results are in line with a previous study, in which MHD patients performed 24% less physical activity count on dialysis days [3]. It can be speculated that this diminished physical activity in dialysis days is caused by the period of inactivity for the dialysis procedure and also to the post-dialysis fatigue syndrome. Nonetheless, as physical activity on non-dialysis days still falls within the sedentary to low active range for number of steps per day and PAL, the reason for the inactivity is not likely imposed only by the dialysis procedure itself. In view of these findings, MHD should be encouraged to enhance their physical activity on a daily basis. In addition, the possibility to incorporate exercise training during the dialysis treatment could also be considered in order to diminish the difference between the dialysis and non-dialysis days.

The factors associated with the low level of physical activity found in this, and in other reports [3–5, 8], are not clear, but it is probably related to the diminished lean body mass [2], aging [6] and to the co-morbidities often observed in MHD patients, such as obesity, PEW, inflammation, diabetes, hyperparathyroidism, anaemia and cardiovascular disease, which may interfere diminishing physical activity [1]. In fact, we observed that age, BMI and CRP were negatively associated with almost all measurements of physical activity assessed. In addition, S-creatinine, a marker of muscle mass, morbidity and mortality in MHD [21], was positively associated with TEE and number of steps per day. Finally, in the multiple regression analysis, age and diabetes were the main determinants of number of steps per day, while BMI and diabetes were the independent determinants of PAL. Altogether, these findings are suggestive that age, diabetes and BMI play an important role on the low level of physical activity found in the MHD population. However, due to the cross-sectional design of our study, we cannot infer causality between those independent determinants and low physical activity. In order to affirm these findings, a longitudinal study is necessary. Therefore, our observation regarding associations between low-level physical activity and the aforementioned parameters refers to a speculative perspective.

The importance of our findings related to PAL should be mentioned. Investigating the PAL is important to better estimate the energy requirements of a given population [15]. In CKD patients, to the best of our knowledge, only one study has assessed PAL in MHD patients, but in a small sample (n = 20). Majchrzak *et al.* [3] found a PAL of 1.22–1.29 which is lower than that observed in our study (1.39 ± 0.2). The results found by us and Majchrzak *et al.* [3] support the notion that the PAL of this population is compatible to a sedentary lifestyle, if we consider the threshold for sedentary or light activity proposed by WHO (PAL: 1.40–1.69) [15]. Therefore, if one wants to individualize the estimation of energy requirements of end-stage renal disease patients, as proposed by the European Best Practice Guideline on Nutrition [22], it is possible that a PAL within the range of sedentary or light activity lifestyle proposed by WHO could be used. However, this subject requires further investigation in a population comprised by MHD.

The main strengths of our study are the relatively large number of patients from various countries, ages and co-morbidities and the application of a methodology which delivers a wide range of measurements of physical activity over several days (including overnight). On the other hand, our main limitation is that TEE and physical activity were not assessed by a technique of high precision. DLW is considered the most precise method for the assessment of TEE and PAL. However, as DLW evaluates the TEE by the disappearance rate of the labelled isotopes in the urine, this technique would be difficult or unfeasible in MHD. For this reason, the use of physical activity monitors, such as SWA, appears of value in MHD patients. Moreover, the SWA allows the assessment of some information (i.e. number of steps per day and activity-related EE) that cannot be evaluated by DLW.

In conclusion, this multicentre international study showed that physical activity and activity-related EE in MHD patients are compatible with a very sedentary lifestyle. This inactivity is worsened by aging, higher BMI and diabetes. The low degree of physical activity found in our investigation emphasizes the importance of the health care team to encourage the MHD patients to increase their physical activity.

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(See related article by Manfredini *et al*. The burden of physical inactivity in chronic kidney disease: is there an exit strategy?. *Nephrol Dial Transplant* 2012; 27: 2143–2145.)

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