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ORIGINAL RESEARCH

What motivates heart transplantation patients to exercise and engage in physical activity? A network analysis

Elena Marques-Sule [1], Dominique Hansen [2], Luis Almenar [3,4], Pallav Deka [5], Trinidad Sentandreu-Mañó [6], Raquel López-Vilella [3], Leonie Klompstra [7], and Felipe V.C. Machado [2]*

[1]Physiotherapy in Motion, Multispeciality Research Group (PTinMOTION), Department of Physiotherapy, University of Valencia, Spain; [2]REVAL-Rehabilitation Research Center, Faculty of Rehabilitation Sciences, Hasselt University, Building A, 3590 Agoralaan, Diepenbeek, Belgium; [3]Heart Failure and Transplantation Unit, Department of Cardiology, Hospital Universitario y Politécnico La Fe, Valencia, Spain; [4]Centro de Investigación Biomédica en Red de Enfermedades Cardiovasculares (CIBERCV), Instituto de Salud Carlos III, Madrid, Spain; [5]College of Nursing, Michigan State University, East Lansing, MI, USA; [6]Department of Physiotherapy, University of Valencia, Valencia 46010, Spain; and [7]Department of Health, Medicine and Caring Sciences, Linkoping University, Linkoping, Östergötland, Sweden

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Aims

After heart transplantation (HTx), increments in physical activity (PA) are strongly recommended. However, participation rates in exercise-based cardiac rehabilitation and engagement in PA are insufficient in many patients. Hence, this study aimed to explore the central factors and the interconnections among distinct types of motivation to exercise, PA, sedentary time, psychosomatic, diet, and activity limitation characteristics in post-HTx patients.

Methods and results

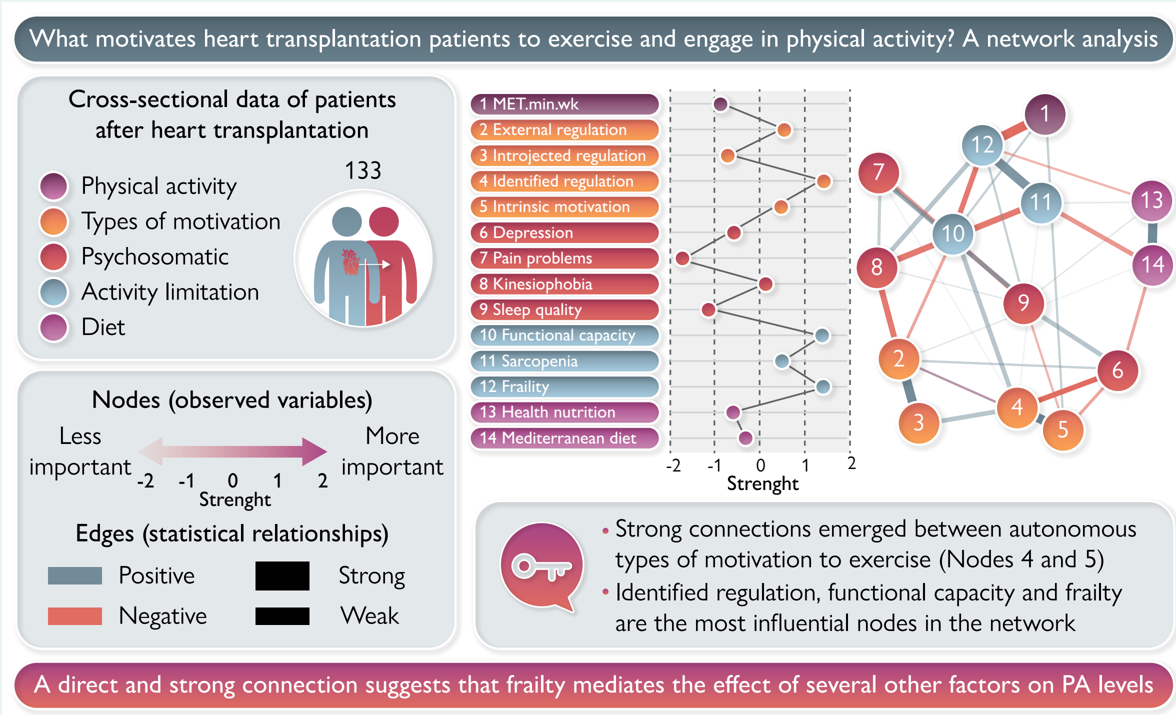
This is a cross-sectional study involving 133 post-HTx patients (79 men, mean age 57 ± 13 years, mean time from transplantation 55 ± 42 months) recruited from an outpatient clinic in Spain. The patients were asked to fill in questionnaires measuring self-reported PA, motivation to exercise, kinesiophobia, musculoskeletal pain, quality of sleep, depression, functional capacity, frailty, sarcopenia risk, and diet quality. Two network structures were estimated: one network including PA and one network including sedentary time as nodes. The relative importance of each node in the network structures was determined using centrality analyses. According to the strength centrality index, functional capacity and identified regulation (subtypes of motivation to exercise) are the two most central nodes of the network (strength: z-score = 1.35–1.51). Strong and direct connections emerged between frailty and PA and between sarcopenia risk and sedentary time.

Conclusion

Functional capacity and autonomous motivation to exercise are the most promising targets of interventions to improve PA levels and sedentary time in post-HTx patients. Furthermore, frailty and sarcopenia risk were found to mediate the effects of several other factors on PA and sedentary time.

* Corresponding author. Tel: +32 469 19 51 91, Email: felipe.machado@uhasselt.be

Graphical Abstract



Keywords Motivation • Physical activity • Sedentary behaviour • Heart transplantation

Novelty

- The findings of this study suggest that interventions to increase physical activity (PA) and reduce sedentary time in post-heart transplantation (HTx) patients should focus more on autonomous types of motivation to exercise.
- Although patients can be motivated, poor functional capacity may hinder participation in regular moderate to high-intensity PA.
- Frailty and sarcopenia are the main mediators of physical inactivity and sedentary behaviour in post-HTx patients.

Introduction

Heart transplantation (HTx) is the recommended treatment for eligible patients with end-stage heart failure (HF) to enhance survival, functional status, and health-related quality of life.[1,2] Participation in exercise-based cardiac rehabilitation post-HTx is recommended for improving exercise capacity, lowering 1-year readmission risk, and long-term survival.[3–5] However, 4–6 weeks post-HTx, patients decrease physical activity (PA) levels, expend 22% less energy, and walk 72% fewer steps per day compared with age, gender, and body mass index (BMI)-matched healthy subjects.[6] Moreover, even though some longitudinal studies suggest that the PA of post-HTx patients significantly increases after 12 months,[6,7] they fail to attain a level of PA comparable with that of healthy subjects,[6] reflected by no significant change in sedentary time during follow-up.[6,7]

A large body of evidence suggests that increased PA and reduced sedentary time are associated with health benefits among patients with cardiovascular disease and the general population.[8,9] Accordingly, PA counselling is one of the cardiac rehabilitation components revised by a recent position paper released by the European Association of Preventive Cardiology.[10] The revised aims of PA counselling include: (i) exploring motivation and opportunities to increase the PA level and (ii) recommending the performance of at least 150 min of moderate-intensity or 75 min of vigorous-intensity aerobic PA a week or an equivalent combination thereof.[10] However, to offer effective PA counselling, it is essential to understand the barriers and motivation to engage in PA in patients with cardiovascular disease, such as post-HTx patients.

A recent study on nearly 600 transplant recipients (58% kidney, 22% liver, 15% lung, and 5% heart) presented regression models that could only explain 30 and 13% (adjusted R^2) of the variation in PA and sedentary time, respectively.[11] In this study, physical limitations, as assessed by the Barriers and Motivators Questionnaire, were the variables strongly related to PA and sedentary time after transplantation.[11] These findings demonstrate that understanding the PA patterns and predictors in post-HTx patients is a complex task. Previous studies have shown associations between increased motivation to exercise and improved PA patterns in different patient populations and healthy volunteers.[12–15] In addition, psychosomatic characteristics, such as depression, kinesiophobia, and sleep quality, were also associated with lower levels of PA in patients with HF and post-HTx.[16–18] While the core components of cardiac rehabilitation include the prevention of sarcopenia and frailty,[10] no study has investigated the impact of frailty and sarcopenia on PA in the years following HTx. Therefore, a better understanding of the factors associated with PA and sedentary time in post-HTx patients remains to be provided.

Network analysis is a relatively new statistical approach that can model complex interactions between many variables.[19,20] This approach facilitates understanding different types of relationships and interactions among variables and identifying central variables that play the most crucial role in the network.[19,20] To the best of our knowledge, no study has used this method to study the interconnection of distinct types of motivation to exercise, different psychosomatic, diet and activity limitation characteristics, and PA profiles in post-HTx patients. Thus, this study aimed to use network analysis to explore the central factors and interconnections of PA, sedentary time, distinct types of motivation to exercise, kinesiophobia, musculoskeletal pain, sleep quality, symptoms of depression, diet, sarcopenia risk, frailty, and functional capacity in post-HTx patients.

Methods

Study design and sample

This cross-sectional study recruited patients from an outpatient clinic in Spain between September 2021 and April 2022. Patients were identified and approached for recruitment by a cardiologist during face-to-face consultations. Inclusion criteria were: (i) to be haemodynamically stable, (ii) to not use walking aids, and (iii) absence of recent symptoms of thoracic pain suggestive of infections or ischaemia. This study was conducted in accordance with the amended Declaration of Helsinki. Informed consent was obtained before the assessments were performed. The study was approved by the Ethics Committee of the University of Valencia (IE1529273). Patients were asked to fill out a set of questionnaires within one visit. Internal consistency measured by Cronbach's α was adequate (0.64–0.91) for all scales[21] (see Supplementary material online, *Table S1*).

Outcomes and tools

Sociodemographic information

The questionnaire consisted of gender, age, BMI, marital status, working status, education level, smoking status, the date of transplantation, and comorbidities.

Physical activity

Physical activity was measured by the short-form International Physical Activity Questionnaire (IPAQ).[22] The short-form IPAQ contains items identifying the frequency and duration of four activity categories: vigorous activities, moderate activities, walking, and time spent sitting on a chair in the last week (sedentary time).[22] The answers to the questions were transformed into time in minutes per week for each PA category. The total PA volume was calculated as the sum of vigorous, moderate, and walking in the metabolic equivalent of task-minutes per week (MET min week). In 2003, Craig *et al.*[22] established the reliability (2 measurements <10 days apart) and validity (compared with accelerometer data) of the IPAQ.

Motivation to exercise

Motivation to exercise was measured with the Self-Regulation Questionnaire-Motivation to Exercise (SRQ-E).[23] The SRQ-E is a validated instrument that contains 16 questions about motivations for engagement in regular exercising. For each question, the scale ranges from 1 to 7, with a score of 1 being 'not at all true' and 7 being 'very true'. Four subscales can be calculated by averaging the responses to each of the four subscales' items: external regulation, introjected regulation, identified regulation, and intrinsic motivation. Higher scores represent a higher level of motivation. The format of these questionnaires was introduced by Ryan and Connell[24] based on the Self-Determination Theory.[25]

Kinesiophobia

Kinesiophobia was evaluated with the Tampa Scale for Kinesiophobia-11 (TSK-11).[26] The TSK-11 consists of 11 items with a four-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). These values yield a total score ranging from 11 to 44, with higher values representing a higher fear of movement. This scale has shown good reliability (internal consistency and stability) and validity (convergent and predictive).[26]

Musculoskeletal pain

Musculoskeletal pain was assessed using the Musculoskeletal System Assessment Inventory (MSSAI).[27] The instrument comprises seven items assessing general information related to musculoskeletal pain, with dichotomous response options (yes = 1 or no = 0). A variable named *Pain problems* was calculated by summing all item scores. The total score ranges from 0 to 7, with higher values indicating more musculoskeletal pain problems.[27]

Quality of sleep

Quality of sleep was measured with the Minimal Insomnia Symptom Scale (MISS).[28] The questionnaire comprises three items, each describing one prominent feature of insomnia, i.e. difficulties falling asleep, night awakenings, and not being rested by sleep. The items have 5 response alternatives ranging from 0 (no problem) to 4 (very severe problems). This yields a score between 0 and 12, with higher scores indicating more severe insomnia.[28]

Depression

Depression was assessed using the eight-item Neuro-QOL v1.0—Depression—Short Form.[29] Each item has 5 response choices ranging from 1 (never) to 5 (always). The total score ranges from 8 to 40, with higher values indicating higher levels of depression.[29]

Functional capacity

Functional capacity was measured with the Duke Activity Status Index (DASI), a questionnaire that correlates with peak oxygen uptake (VO_2peak) and metabolic equivalents (METs), with established internal consistency (Cronbach's α of 0.72).[30] The instrument includes 12 activities related to personal care, ambulation, household tasks, sexual function, and recreational activities. Each item answered positively is assigned an estimated weight that allows total scores between 0 and 58.2. Higher scores represent better functional capacity.[30]

Frailty

Frailty was measured using the FRESH-screening instrument. It consists of five items related to tiredness, falls, endurance, needing support while shopping, and three or more visits to the emergency department in the past 12 months.[31] Subjects were considered to be at risk of frailty by answering 'yes' to two or more of these five questions.[31]

Sarcopenia risk

Sarcopenia risk was assessed with the SARC-F questionnaire.[32] This questionnaire includes five components: strength, walking, rising from a chair, climbing stairs, and experiencing falls. Each component is scored between 0 and 2, which yields a total score between 0 and 10. Higher scores represent higher sarcopenia risk, and patients with a score of ≥4 points are considered symptomatic.[32]

Diet quality

Diet quality was assessed using the Index of Healthy Nutrition (IHN) and the Mediterranean Diet Adherence Screener (MEDAS-14).[33,34] Participants were asked about the frequency of consumption of 10 food groups.[33] The total IHN score is the sum of the scores obtained for each food group. A higher IHN score denotes a better diet quality. The MEDAS-14 consists of 14 questions: 12 about food consumption frequency and 2 about food intake habits considered characteristic of the Mediterranean Diet.[34] The participants' responses to each question were valued as 0 or 1. This yields a score between 0 and 14, with higher scores indicating more adherence to the Mediterranean Diet.

Statistical analysis

The statistical analysis was conducted using JASP 0.16.3.0.[35] Quantitative data were described as mean values and standard deviations (SDs) or median and 25–75 interquartile range, according to normality in data distribution. Qualitative data were expressed as absolute and relative frequencies. There were no missing data. The network analysis was conducted using the Network Module based on the R packages *bootnet*[20] and *qgraph*.[36] A network consists of 'nodes' representing the observed variables connected by 'edges' representing statistical relationships.[20] In this study, two networks were estimated: one with PA volume (MET min week) and one with sedentary time per week (min/week) as nodes. A partial correlation network was estimated using the graphical Least Absolute Shrinkage and Selection Operator (gLASSO), which results in edges representing partial correlation coefficients between two variables after conditioning on all other variables in the data set.[20,37] As gLASSO produces a collection of network solutions, the Extended Bayesian Information Criterion (EBIC) was used to select the optimal network model.[20,38] The higher the partial correlation coefficients between two nodes, the thicker the edge (edge-weight) shown in the network graphic.[19,20] Nodes with more or stronger connections are placed closer together, while nodes with fewer connections are set further apart. To assess the accuracy of the estimated edge weights, 95% confidence intervals (CIs) were estimated based on non-parametric bootstrapping ($n = 1000$ boots).

The centrality indices (strength, betweenness, and closeness) are reported as standardized z-scores (mean = 0, SD = 1).[20] The strength index represents the overall influence of a node in the network and is based on the sum of the weighted number and strength of all connections to that specific node.[19] The betweenness index provides information on how important a node is to connect other network nodes, a characteristic of nodes that act as a bridge.[19] The closeness index quantifies the number of direct and indirect links between the node of interest to all other nodes in the network; a node with high closeness will be affected quickly by changes in any part of the network.[19] The stability of the centrality indices was investigated by the case-dropping subset bootstrap approach ($n = 1000$ boots), which estimates network models based on subsets of the data.[19,20]

Results

From a total of 285 patients assessed for eligibility, 133 patients participated in the study. The main reason for exclusion was unwillingness to participate ($n = 94$). *Table 1* displays the anthropometric and sociodemographic characteristics of the sample. A total of 133 patients [79 men, mean age 57 (SD 13) years, mean BMI 24.5 (SD 4.1) kg/m^2] were included. The mean time from transplantation was 55 months (SD 42). Most of the patients were married (78%), retired (82%), former smokers (61%), and completed secondary education (44%). The prevalence of hypertension, diabetes, and dyslipidaemia were 32, 26, and 23%, respectively. The time from transplantation (r_s: −0.42, $P <$ 0.001) and BMI (r_s: −0.20, $P = 0.021$) were negatively correlated with sedentary time per week. Patients who completed primary education showed a higher sedentary time than the other groups ($P < 0.04$, for all pairwise comparisons). Patients with diabetes showed lower PA volume in comparison with patients without diabetes ($P = 0.011$). *Table 2* displays the scores of PA and motivation to exercise as well as the psychosomatic, diet and activity limitation characteristics of the sample.

Table 1 Anthropometric and sociodemographic characteristics of the sample

Variable	All patients ($n = 133$)
Male, *n* (%)	79 (59)
Age (years)	57 ± 13
BMI (kg/m^2)	24.5 ± 4.1
Time from transplantation (months)	55 ± 42
Marital status, *n* (%)	
Married/partner	104 (78)
Single	17 (13)
Widow	6 (4.5)
Divorced	6 (4.5)
Working status, *n* (%)	
Working	10 (7)
Unemployed	13 (10)
Retired	110 (83)
Education, *n* (%)	
No education	10 (8)
Primary	31 (23)
Secondary	59 (44)
University	33 (25)
Smoking status, *n* (%)	
Never smoker	51 (38)
Former smoker	81 (61)
Smoker	1 (1)
Comorbidities, *n* (%)	
Hypertension	43 (32)
Diabetes	35 (26)
Dyslipidaemia	31 (23)

Data are described as mean values (SDs), or absolute and relative frequencies.
BMI, body mass index.

Figure 1 shows the network plots based on the EBIC gLASSO estimation when using PA volume (MET min week) as one of the nodes. Strong connections emerged between Node 2 (SRQ-E external regulation) and Node 3 (SRQ-E introjected regulation), Node 4 (SRQ-E identified regulation) and Node 5 (SRQ-E intrinsic motivation), Node 13 (health nutrition) and Node 14 (Mediterranean diet), as well as among Nodes 10 (functional capacity), 11 (sarcopenia), and 12 (frailty). Remarkably, Node 1 (PA volume) presented a strong connection with Node 12 (frailty). Moreover, Node 1 (PA volume) also showed direct connections with Nodes 5 (SRQ-E intrinsic motivation), 6 (depression), 8 (kinesiophobia), and 10 (functional capacity). According to the centrality indices (see Supplementary material online, *Figure S1*), Node 10 (functional capacity) is the most central node of the network (strength: z-score = 1.43, betweenness: z-score = 2.46, closeness: z-score = 2.25). In addition, based on the strength index, Nodes 4 (SRQ-E identified regulation; z-score = 1.40) and 12 (frailty; z-score = 1.40) were also highly influential nodes.

Figure 2 shows the network plots based on the EBIC gLASSO estimation using sedentary time per week (min/week) as one of the nodes. As expected, a similar pattern of strong connections was found compared with the previous network. Node 1 (sedentary time) presented several direct connections. These connections (in order of strength) emerged with Nodes 11 (sarcopenia), 6 (depression), 4 (SRQ-E identified regulation), 2 (SRQ-E external regulation), 10 (functional capacity), 5 (SRQ-E intrinsic motivation), 12 (frailty), and 14 (Mediterranean diet). According to the centrality indices (see Supplementary material online, *Figure S2*), Node 4 (SRQ-E identified regulation) and Node 10 (functional capacity) were the most central nodes (strength: z-score = 1.51 and 1.35, respectively). Based on the betweenness index, Node 11 (sarcopenia) was identified as an essential bridge in this network (betweenness: z-score = 2.30).

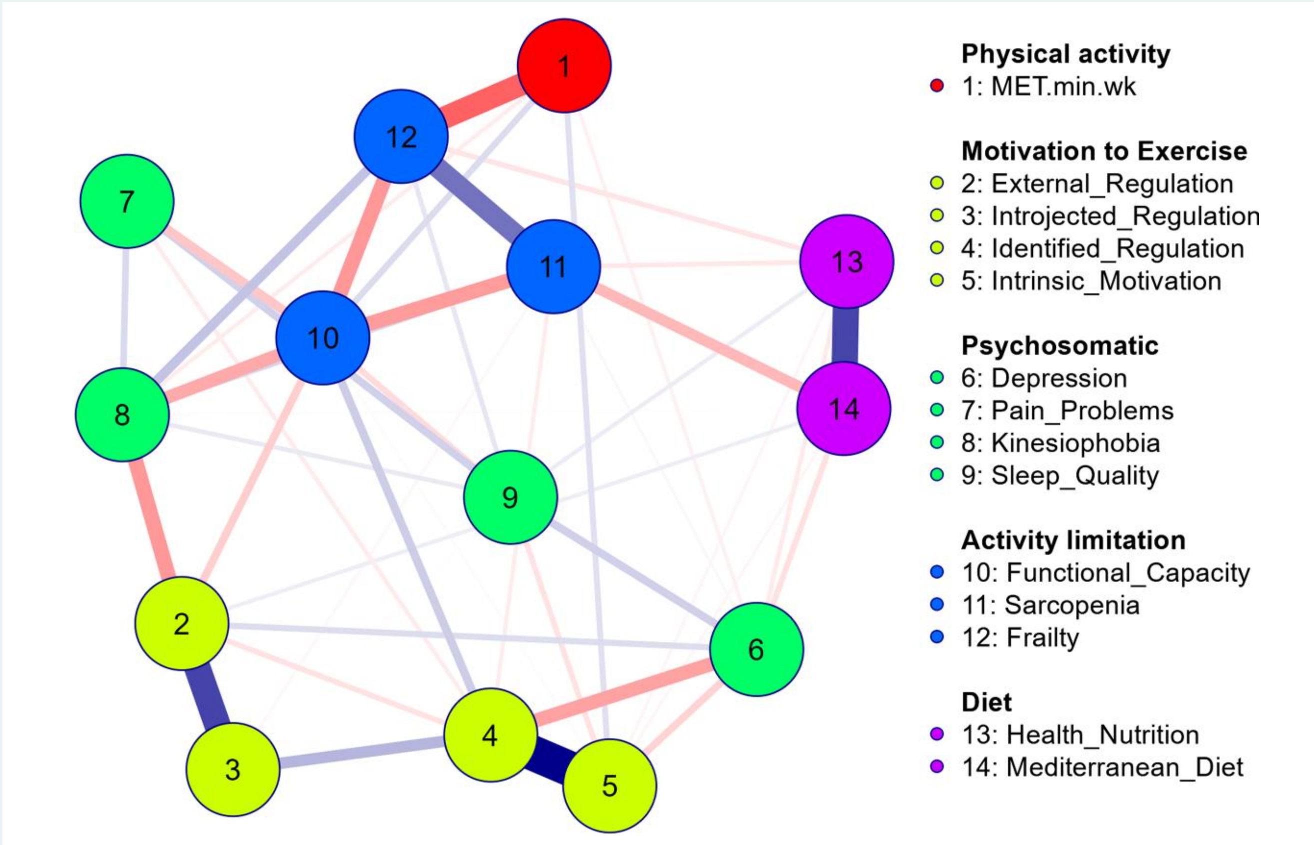


Figure 1 Network plots of the estimated Extended Bayesian Information Criterion graphical Least Absolute Shrinkage and Selection Operator networks using the physical activity volume (MET min week) as one of the nodes. Each node represents a variable, whereas each edge represents the partial correlation (blue = positive, red = negative). Thicker edges represent more robust associations.

Supplementary material online, *Figures S3* and *S4* show the bootstrapped 95% CIs of edge weights for the networks. The estimations of the edge weights are sufficiently accurate to be interpreted since the CIs of the edge weights are not excessively large. However, sizable CIs around the estimated edge weights indicate that many edge weights likely do not significantly differ. Supplementary material online, *Figures S5* and *S6* show that the average correlation with the original sample for the strength and closeness indices decreases relatively slowly when increasing participants are dropped from the entire data set. This indicates that the stability of these indices in both networks is moderate and can be reliably interpreted. On the other hand, the average correlation with the original sample for the betweenness index decreases steeply and substantially when an increasing number of participants are dropped from the entire data set (below <0.75 after removing 60% of the sample) for both networks. This indicates that the order of node betweenness is interpretable with some care (*Table 2*).

Discussion

This is the first study to apply a network analysis approach to investigate the interconnection of distinct types of motivation to exercise, different psychosomatic, diet and activity limitation characteristics, and PA and sedentary behaviour in post-HTx patients. Functional capacity as assessed by the DASI questionnaire and the identified regulation subscale measured by the SRQ-E instrument were the two most influential factors in both networks (i.e. the network including PA volume or sedentary time as nodes). Furthermore, frailty and sarcopenia risk were found to play an essential role in these networks based on their strong and direct connections with PA volume and sedentary time.

Klompstra *et al.*[12,13] found positive associations between motivation to exercise and PA in Swedish and Spanish patients with HF. However, the association between motivation to exercise and PA was mediated by exercise self-efficacy and PA enjoyment.[12,13] Segatto *et al.*[14] demonstrated that autonomous self-regulation (a combined score of identified regulation and intrinsic motivation) was significantly and positively related to health-enhancing PA among transplant recipients. Moreover, a recent study by Esmaeilzadeh *et al.*[15] found that intrinsic motivation directly and negatively predicted sitting time ($\beta = -0.14$, $P = 0.01$) but directly and positively predicted PA ($\beta = 0.40$, $P < 0.01$) in 629 Finnish adults and older adults. In this previous study, none of the other subscales had any significant relationship to PA or sitting time.[15] Since our findings demonstrate that identified regulation is one of the nodes with the highest strength in both networks, it seems vital for healthcare professionals to investigate the probable reasons and the type of motivation to exercise in post-HTx patients.

Interestingly, functional capacity was one of the central variables in our network analysis. Even though an individual may have higher levels of more autonomous types of motivation, poor functional capacity may hinder participation in regular moderate to high-intensity PA. This was demonstrated in patients with chronic obstructive pulmonary disease since the likelihood of improving PA following pulmonary rehabilitation was significantly higher in patients with greater baseline exercise

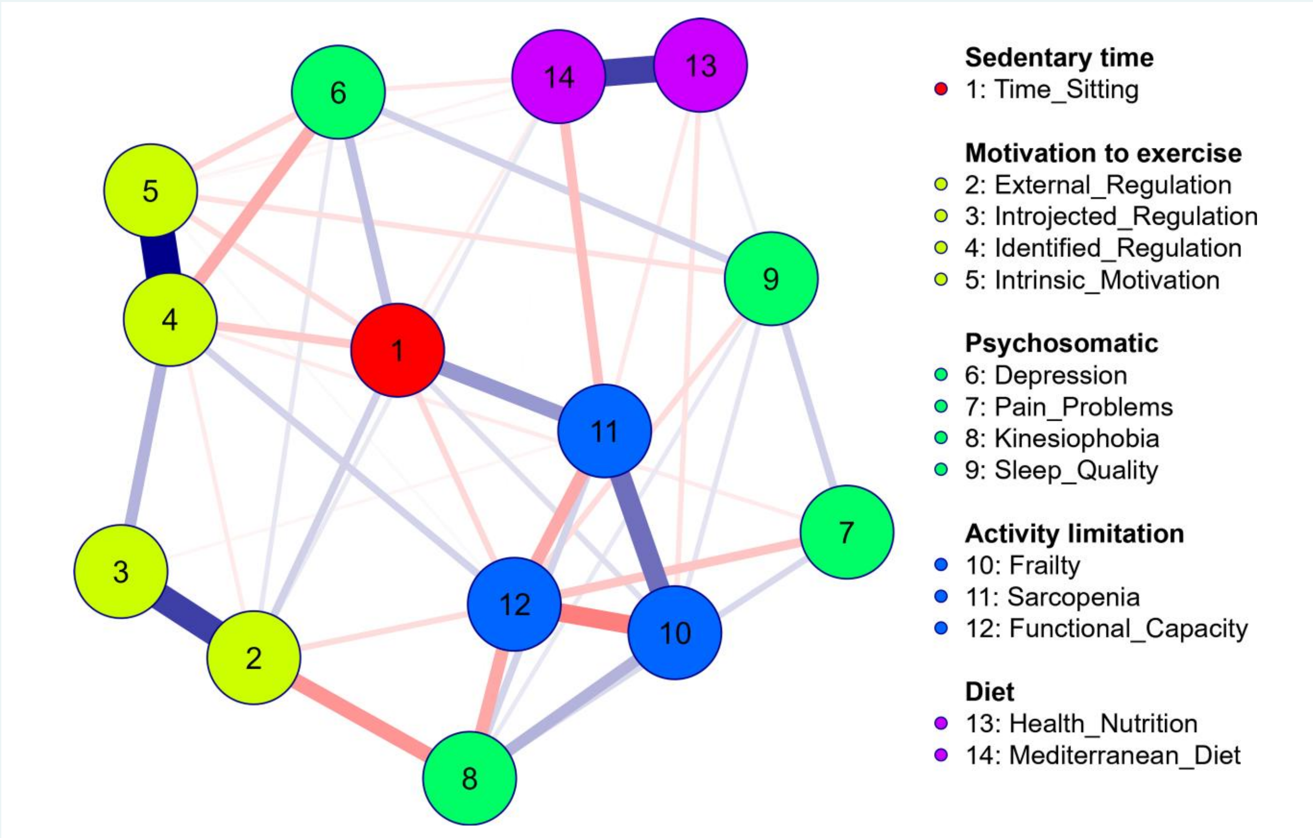


Figure 2 Network plots of the estimated Extended Bayesian Information Criterion graphical Least Absolute Shrinkage and Selection Operator networks using sedentary time per week (min/week) as one of the nodes. Each node represents a variable, whereas each edge represents the partial correlation (blue = positive, red = negative). Thicker edges represent more robust associations.

tolerance than those with lower levels.[39] Yardley *et al.*[40] compared post-HTx patients who participated in a 12-month high-intensity interval training (HIIT) intervention with usual care. Remarkably, both groups showed relatively preserved aerobic performance (VO_2peak of 75% of predicted) and were physically active, with >1 h of moderate-intensity activity per day, at the 5-year follow-up.[40] However, patients who completed a 12-month HIIT intervention with an initial significant increase in exercise capacity could not maintain this higher post-exercise VO_2peak level during the next 4-year follow-up period.[40] Therefore, healthcare professionals working with post-HTx patients should regularly assess their functional capacity for a prolonged period after transplantation. Patients may benefit from repeated participation in exercise programmes to maintain the positive effects on exercise capacity, which can facilitate the performance of social, recreational, and daily activities.

It has been demonstrated that frailty within 6 months before HTx is associated with increased mortality and prolonged hospitalization after HTx.[41] Evidence suggests that sarcopenia is also associated with mortality in this population since patients with a low psoas muscle area before HTx had a three-fold increase in mortality risk (odds ratio, 3.03; 95% CI, 0.92–9.97).[42] Our results demonstrated that the association between sarcopenia and PA volume could be explained by frailty (i.e. no direct connections between sarcopenia risk and PA volume). In contrast, in the network using sedentary time as one of the nodes, frailty showed a direct and indirect connection with sedentary time, the latter through a common link with sarcopenia risk. This study adds to the current literature by revealing that frailty and sarcopenia might be the primary mediators of the effect of other variables on PA volume and sedentary time after HTx.

Our study did have some limitations. First, our measures were self-reported, and including objective measurements of PA, exercise tolerance, skeletal muscle mass, and function would strengthen our findings. Second, other variables associated with PA in post-HTx patients, such as self-efficacy, anxiety, access to rehabilitation programmes, and PA enjoyment, were not assessed. A qualitative, interview-based investigation explored why people with HF do and do not engage in regular PA.[43] This study demonstrated several extrinsic and intrinsic factors influencing PA, such as family, social support, and environmental influences,[43] that could not be added as nodes in our network analysis. Third, the cross-sectional design of our study does not allow the investigation of whether the change in PA over time is influenced by different factors, such as baseline levels of motivation to exercise and functional capacity, as well as the presence of sarcopenia and frailty. Finally, a larger sample size could result in a more stable network, given a large number of variables and associations to be estimated. However, to tackle this potential limitation, we used the gLASSO estimation, which is particularly suitable for smaller samples as it returns a sparse network model where the number of parameters that need to be estimated is reduced.[20] Remarkably, there still needs to be an established method for a formal power analysis or a minimal sample size required for this type of analysis. Indeed, the main strength of this study is the use of network analysis in a well-characterized sample of post-HTx patients. This allowed the identification of the most central variables and understanding of the complex interactions among distinct types of motivation to

Table 2 Physical activity, musculoskeletal pain, frailty, sarcopenia risk, kinesiophobia, functional capacity, depression, quality of sleep, and diet characteristics in 133 patients after heart transplantation

Variable	All patients (n = 133)
IPAQ	
Walking time (min/week)	315 (90–540)
Sedentary time (min/week)	360 (240–600)
Physical activity volume (MET min week)	1386 (297–2212)
Frailty and sarcopenia screening	
FRESH total score	1 (0–2)
Frailty, *n* (%)	47 (35)
SARC-F total score	1 (0–3)
Sarcopenia risk, *n* (%)	21 (16)
MSSAI pain problems	3 (0–5)
TSK-11	25 (20–31)
DASI	33 (19–45)
NeuroQOL depression	13 (8–18)
MISS	4 (2–7)
IHN	76 (70–82)
MEDAS-14	10 (9–11)

Unless otherwise stated, data are described as median and 25–75 interquartile range. DASI, Duke Activity Status Index; IHN, Index of Healthy Nutrition; IPAQ, International Physical Activity Questionnaire; MEDAS-14, Mediterranean Diet Adherence Screener; MISS, Minimal Insomnia Symptom Scale; MSSAI, Musculoskeletal System Assessment Inventory; SARC-F, Strength, Walking, Rising from a chair, Climbing stairs and Experiencing falls; TSK-11, Tampa Scale for Kinesiophobia-11.

exercise, psychosomatic, diet and activity limitation characteristics, and PA profiles in post-HTx patients.

Following HTx, a comprehensive intervention may be required to reduce the recurrence or incidence of cardiovascular disease and to improve survival and post-transplant quality of life. In addition to exercise-based cardiac rehabilitation, lifestyle modification with PA counselling may be feasible to enhance health by improving this population's quality of life, cardiovascular risk factors, and metabolism. Physical activity counselling should aim for advice on appropriate activities and the determination of exercise intensity based on perceived exertion rather than heart rate (due to the denervation of the heart).[10] The World Health Organization 2020 guidelines on PA and sedentary behaviour provide a new recommendation for reducing sedentary behaviours and participating in regular moderate-to-vigorous intensity PA.[44] Therefore, interventions to reduce sedentary time should also be essential to managing post-HTx patients.

Conclusions

In summary, this study, conducted in a well-characterized sample of post-HTx patients, demonstrates that functional capacity and more autonomous types of motivation to exercise (i.e. intrinsic motivation and identified regulation) are the most promising targets of interventions to improve PA levels and sedentary time in this population. Furthermore, since strong and direct connections emerged between these variables, frailty and sarcopenia risk were found to mediate the effect of several other factors on PA levels and sedentary time. Future clinical trials to increase PA and reduce sedentary time in post-HTx patients should consider tailoring the intervention according to the patient's functional capacity and incorporating motivational strategies focusing more on autonomous motivation types.

Author contributions

E.M.-S., D.H., and F.V.C.M.: conceptualization, writing—original draft, formal analysis, and visualization; L.A., P.D., T.S.-M., R.L.-V., and L.K.: validation and writing—review and editing. All of the authors contributed in the design of the work and revising the draft and approved the final version of the manuscript.

Supplementary material

Supplementary material is available at *European Journal of Cardiovascular Nursing* online.

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Conflict of interest: None declared.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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