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An individual rehabilitation project in patients undergoing allogeneic hematopoietic stem cell transplantation

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ABSTRACT

Background: Allogeneic hematopoietic stem cell transplantation (allo-HSCT) is a curative option for various hematological diseases but often leads to physical deconditioning, fatigue, and reduced quality of life (QoL). Rehabilitation, through therapeutic exercise (TE), may counteract these complications. This study evaluated the feasibility and safety (clinical effects as secondary aims) of an Individual Rehabilitation Project (IRP) integrating TE during hospitalization and post-discharge in patients after allo-HSCT.

Methods: Prospective longitudinal, uncontrolled study conducted at Tor Vergata University Hospital, Rome, Italy. The IRP comprised six weekly supervised TE sessions during hospitalization and a personalized post-discharge exercise plan. Functional independence (Barthel Index), fatigue (Fatigue Severity Scale), aerobic/anaerobic fitness (Six-Minute Walking Test, 30-Second Sit-to-Stand Test), and perceived exertion (Modified Borg Scale) were assessed at baseline (T1), discharge (T2), 100 days (T3), and 6 months post-transplant (T4). Repeated measures ANOVA with Bonferroni corrections analyzed temporal changes.

Results: Forty-seven patients were enrolled, and 33 completed the study. All survivors at 180 days completed the IRP without adverse events (CTCAE v5.0). Significant changes over time were observed for fatigue ($p = 0.001$), 6-Minute Walking Test ($p = 0.007$), 30-Second Sit-to-Stand Test ($p < 0.001$), and Borg Scale ($p = 0.007$), whereas the Barthel Index remained stable ($p = 0.430$). Fatigue and perceived exertion increased significantly at discharge and subsequently improved, while functional performance declined in the early post-transplant phase and recovered progressively by T4.

Conclusions: The IRP integrating TE was feasible, safe, and associated with reduced fatigue and improved physical capacity after allo-HSCT. Although limited by the lack of a control group, these findings support structured rehabilitation in this population.

1. Introduction

Allogeneic Hematopoietic Stem Cell Transplantation (allo-HSCT) is the only curative approach for many hematological diseases. With advancements in techniques, allo-HSCT has led to a significant reduction in mortality, but functional and quality of life (QoL) outcomes are still often poor (Kurosawa et al., 2015). The allo-HSCT procedure itself is an intensive process, encompassing three phases: pre-transplant conditioning; engraftment phase, characterized by aplasia, in which stem cells are infused into the patient's bloodstream; post-engraftment phase, a recovery phase that marks the re-establishment of the immune system and hematopoietic function (Hematopoietic Stem Cell Transplantation and Bishop, 2009).

The entire allo-HSCT process typically requires 20-30 days of

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hospitalization. While allo-HSCT offers a lifeline for many patients, it can also lead to a range of complications, including significant physical deconditioning, increased fatigue and reduction of independence in activities of daily life (ADLs) (Bruera and Yennurajalingam, 2010). The underlying causes of fatigue are multifaceted, with a key role played by elevated levels of pro-inflammatory cytokines (Mitchell et al., 2014; Galeoto et al., 2018; Mohammed et al., 2019; Persoon et al., 2013; Robinson et al., 2018; Baguley et al., 2017; Steinberg et al., 2015).

Traditionally, patients undergoing allo-HSCT are advised to minimize physical activity (Mitchell et al., 2014; Pearson et al., 2018). However, recent research (Parry and Puthucheary, 2015; Mañas-García et al., 2020) has challenged this notion, highlighting the detrimental effects of inactivity. Prolonged immobility can lead to muscle mass loss, reduced strength and endurance, inflammation, and musculoskeletal sequelae that hinder functional recovery (Parry and Puthucheary, 2015; Mañas-García et al., 2020).

To minimize these problems, a motor re-educational program could be implemented. A motor re-educational program is based on therapeutic exercise (TE), defined as a repetition of a series of acts aimed at maintaining or restoring motor function and reduce complications. TE primarily targets the musculoskeletal system, enhancing muscle tone and reducing fatigue (Cramp and Byron-Daniel, 2012). However, its benefits extend even further, positively influencing psychological, physiological, neurological, respiratory, and immune systems (Galeoto et al., 2018; Steinberg et al., 2015). Furthermore, cancer-related fatigue and physical deconditioning are highly prevalent in patients undergoing allogeneic hematopoietic stem cell transplantation (allo-HSCT). Recent evidence highlights that these patients often suffer from decreased skeletal muscle blood flow and impaired muscle oxygen consumption, which directly limit exercise capacity and exacerbate post-transplant fatigue (Morishita et al., 2019). In this context, structured physical exercise plays a crucial role in countering muscle deconditioning, improving oxygen utilization, and enhancing overall functional recovery.

Consequently, rehabilitation has become a pivotal component of treatment, with a particular emphasis on managing fatigue, both mental and physical (Galeoto et al., 2018). TE benefits could encompass improved endurance, strength, and independence in ADLs. Additionally, physical activity has been shown to exert positive effects on other physiological systems, particularly the hematopoietic system, by accelerating cell recovery (Steinberg et al., 2015; Wiskemann and Huber, 2008). Furthermore, recent systematic reviews and meta-analyses confirm the positive effects of structured physical exercise programs in patients undergoing allo-HSCT, demonstrating significant benefits for recovery and overall clinical outcomes (Pérez-Aguilar et al., 2026; Eid et al., 2026).

Based on these considerations, this prospective study aimed to evaluate the feasibility and safety of a dedicated Individual Rehabilitation Project (IRP) comprising a motor re-educational program carried out during the hospitalization period and after discharge in adult patients undergoing allo-HSCT. Furthermore, a secondary aim was to track and understand recovery trajectories analyzing whether the proposed IRP yielded positive effects on patient-reported fatigue and objective functional capacity.

2. Materials and methods

2.1. Study design, setting and ethical approval

This prospective longitudinal study was conducted at Tor Vergata University Hospital, Rome, Italy. The HSCT unit was the setting during the transplantation process, while the Onco-hematology Day Hospital provided outpatient care and follow-up. This collaborative effort involved the Hematology unit and the Physical and Rehabilitation Medicine (PRM) unit.

The clinical protocol was conducted, recorded and reported in accordance with Good Clinical Practice guidelines and the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 2013). All patients were asked to sign an informed consent form before taking part in the study (Mavrov, 2018). The study protocol was approved by "Lazio Area 2" Ethical Committee (233.22). Since this protocol is based on safety and feasibility as primary outcomes, it was not considered a clinical trial and therefore it was not registered. Adherence to ethical standards has been guaranteed by ethical committee approval.

2.2. Participants

Patients were included in this study if they met the following inclusion criteria: being adults (age between 18 and 70 years), undergoing allo-HSCT from HLA-matched or -mismatched familial or unrelated donors, being treated with a Thiotepa-Fludarabine-Busulfan ± GRAFALON conditioning regimen, presenting stable clinical conditions allowing participation in the protocol activities, being able to understand the protocol and sign informed consent. Patients were excluded if they presented cardiologic, orthopedic, or neurologic diseases with contraindication to active or passive mobilization, psychiatric or other clinical disorders severe enough to interfere with the performance of the IRP tasks, sensory impairments that significantly compromise a participant's ability to complete the study protocol, as severe visual or auditory deficits, physical conditions limiting the ability to receive physiotherapy for at least half of the hospitalization period.

2.3. Intervention

After enrollment, an initial assessment (T1) was conducted jointly by PRM specialists and Hematologists alongside a Physiotherapist (PT) with experience in the re-education of patients with hematologic conditions. The same PT was responsible for the administration of the motor program. During this first visit, a global clinical and functional assessment was performed. Additionally, patients completed standardized independence and physical performance tests. Assessments were repeated at the time of discharge (T2), 100 days post-transplant (T3) and 6 months post-transplant (T4) (Fig. 1). All the assessments were conducted within the same hospital structure.

During hospitalization, the motor re-educational program was administered six days a week, from Monday to Saturday. Each session lasted 20-40 min. The re-educational program included TE aimed at maintaining and improving general physical function, joint mobility, strength and endurance of the upper and lower limbs and trunk, coordination, balance, and muscle flexibility. Breathing exercises were included when clinically appropriate to facilitate breathing control and thoracoabdominal mobility. The intensity of the TEs was at first calibrated based on the initial assessment and then adjusted daily based on the patient's clinical and functional status. During supervised inpatient sessions and study assessments, oxygen saturation, respiratory rate, and heart rate were routinely monitored for clinical safety. The physicians (hematologists or physiatrists) and physiotherapist also monitored symptoms and clinical signs of exercise intolerance, including dyspnea or signs of respiratory distress. The exercise session was adapted accordingly. Dedicated assessments of respiratory mechanics, respiratory muscle strength, and respiratory muscle fatigue were not included, as these domains were not prespecified outcomes of this functional study. Complete blood count was routinely assessed every morning prior to the delivery of any physical therapy session. Patient-reported pain was also considered during supervised sessions and informed the choice, intensity, or modification of exercises according to individual tolerance. Pain was assessed clinically for treatment adaptation but was not systematically recorded using a standardized scale.

When clinically appropriate, sessions included gentle stretching exercises performed slowly, without ballistic movements or forced end-range positions, and within the patient's comfortable range of motion. Stretching was individually tailored and could be modified or omitted

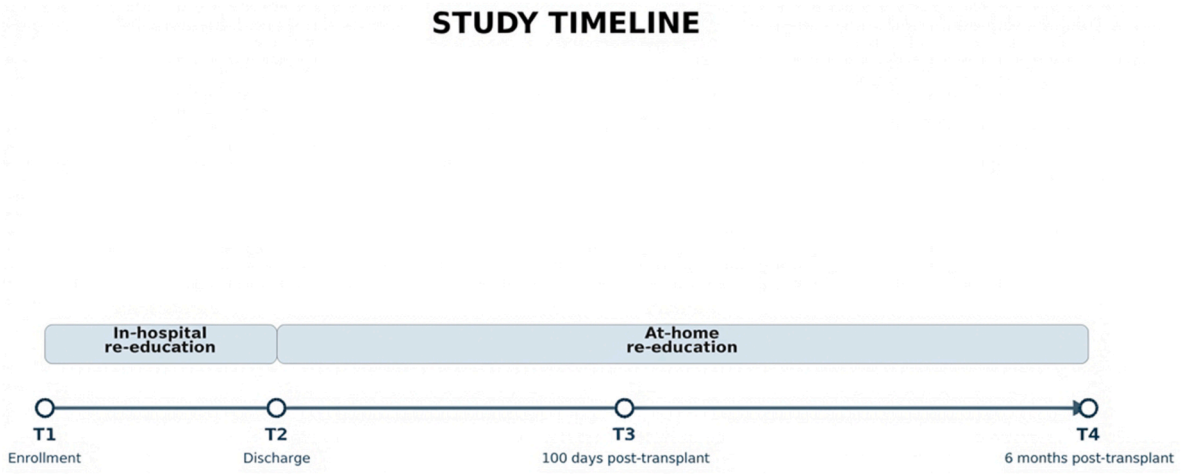


Fig. 1. Study Timeline.

according to the patient's symptoms, clinical condition, daily blood count, and the recommendations of the hematology team.

When clinically feasible after the aplasia phase, out-of-room ambulation training was implemented to re-educate walking ability, increase endurance, and improve aerobic fitness.

At discharge, all patients were advised to gradually resume a normal daily lifestyle and to engage in common physical activities according to their individual capacities, while avoiding excessive strain or overexertion. Moreover, patients were provided with a booklet containing personalized illustrated TEs with detailed descriptions, repetition guidelines, and recovery phases. Patients were instructed to continue these TEs post-discharge, recording their frequency and any challenges on a provided chart. This information was to be shared with the research team during follow-up visits. Post-discharge exercise was self-directed rather than supervised, and no remote monitoring was used. Caregivers did not receive structured training as part of the study protocol, and their contribution to home exercise was not systematically assessed. T4 follow-up assessment always coincided with the patient's scheduled clinical visit in the hematology department. Specifically, the clinician reviewed the patient's medical records, and patients had the opportunity to report any musculoskeletal symptoms, signs, or complications that had emerged over time.

TE explanations, pictures and the booklet given at discharge are available as supplementary materials.

To assess feasibility, we evaluated the intervention's deliverability as intended across both the inpatient hospitalization and post-discharge periods. For the hospital phase, this specifically included evaluating its implementation within the constraints of available staffing and infrastructure resources.

During hospitalization, adherence was assessed from participation in scheduled supervised sessions. After discharge, patients were asked to document exercise frequency and difficulties on a self-report chart; however, adherence during the home-based phase was not independently verified.

Additionally, we recorded study completion rates, distinguishing between participants who concluded the study and those who discontinued due to mortality, withdrawal of consent, or other factors.

Adverse events were recorded during the entire study phase and graded according to Common Terminology Criteria for Adverse Events (CTCAE) v5.0, a standardized classification and grading system for adverse events that occur during trials, particularly in cancer research. CTCAE v5.0 refers to Version 5.0, which is the most recent update of this system, released by the U.S. National Cancer Institute (NCI) in November 2017. CTCAE v5.0 categorizes a wide range of adverse events (e.g., fatigue, nausea, dizziness) and assigns a grade of severity to each.

2.4. Outcome measures

The study employed validated assessment tools to measure functional independence and fatigue [i.e., Barthel Index (BI) and Fatigue Severity Scale (FSS)]. Additionally, the Modified Borg Scale (MBS), Six-Minute Walking Test (6MWT), and the 30-Second Sit-to-Stand Test (30STS) were administered to assess aerobic and anaerobic fitness.

The BI is a scale used to assess ten basic ADLs (i.e., eating, clothing, personal hygiene, bathing/showering, bowel sphincter control, bladder sphincter control, chair/bed transfers, toilet use, walking, climbing and descending stairs). The motor behavior of patients during ADLs is rated on a 0-point to 10-point or 15-point Likert scale, depending on the activity, reflecting their level of independence over the past week. The total score is calculated by summing the scores of individual items and then categorized as follows: 100 (complete independence), 99-91 (near independence), 90-75 (mild dependence), 74-50 (moderate dependence), 49-25 (severe dependence), and <25 (complete dependence) (Wade and Collin, 1988).

The FSS is a nine-item questionnaire used to assess the impact of fatigue on daily life. Patients rate each item on a 7-point Likert scale. The total score ranges from 9 to 63 points, with higher scores indicating greater fatigue severity. A score of 9 suggests minimal fatigue, while a score of 63 indicates that fatigue significantly impairs daily functioning (Krupp, 1989).

The 6MWT is a standardized submaximal physical activity test commonly used to determine functional capacity and endurance. During the 6MWT, participants walk a 25-m course for 6 min, maintaining a comfortable pace. The test environment should be free of distractions to ensure a natural gait pattern. 6MWT is used to assess the total distance covered during the 6-min walking period. This data allows for comparison with baseline measurements and can be used to track changes in functional capacity over time (Enright, 2003; ATS Statement, 2002).

The 30STS was used as a measure of lower-limb functional performance. The test involves asking the patient to stand up and sit down from a chair repeatedly, counting the number of movements performed within 30 s. The test requires the use of a chair of a specific height (approximately 43-45 cm) to allow a seated position with hip and knee flexion at 90°. The number of repetitions performed by the patient is recorded to allow for comparison with subsequent assessments. 30STS does not provide a direct measure of balance or strength in individual muscle groups (Jones et al., 1999).

Perceived exertion was assessed using the MBS. The MBS is a subjective rating scale used to measure the intensity of physical activity. It ranges from 6 to 20 points, with 6 representing “no exertion” and 20 representing “maximal exertion.” The scale is divided into four categories: 6-9 (very light), 10-12 (light), 13-15 (somewhat hard), and 16-20

(very hard). The MBS is commonly used to assess the intensity of physical activity and to monitor individual responses to physical activity. It can be used by people of all ages and fitness levels (Borg, 1982).

2.5. Statistical analysis

Descriptive statistics are computed to describe the collected variable; particularly, frequency with absolute percentage and mean ± standard deviation (SD) were calculated for categorical and continuous variables, respectively.

In order to study the differences between the different assessment points, an ANOVA for repeated measures with post-hoc Bonferroni-corrected tests was performed. To study the effect of the treatment, a mean change (calculated as the average difference between the initial and final assessments) with its 95% confidence interval (95% CI) was calculated for each assessment point. Mauchly's sphericity test was used prior the ANOVA; in case that the sphericity test was not met, Greenhouse–Geisser correction was performed.

All statistical analyses were performed according to the "per protocol" analysis and were run with SPSS software (version 21 for Windows; SPSS Inc., Chicago, IL; 2004). The statistical significance was set for $\alpha = 0.05$.

3. Results

3.1. Participants

Based on similar previous trials (Mello et al., 2003; Baumann et al., 2010), a convenience sample of forty-seven patients (26 females, 55%; mean age 48.2 ± 13.1 years) undergoing allo-HSCT were recruited. The number of patients who declined to participate was 3. Out of the total enrolled participants, 33 completed the comprehensive evaluation phase. Non-completion of the program (n = 14) was attributed to patient mortality that occurred during the hospitalization phase (n = 9) or withdrawal of consent within 10 days from the start (n = 5). Significantly, none of the study discontinuations were due to difficulties encountered during the IRP course, augmented fatigue, or any other IRP-related reasons. The median duration of hospitalization was 35 days (range 30–41). All 33 patients performed at least 90% of the IRP (missed less than one session per week) and were all followed up until 180 days post-transplant. This attendance figure does not include the home-based phase, for which a reliable weekly exercise frequency could not be established.

No patients within the cohort engaged in outpatient rehabilitation following discharge. The detailed demographic and clinical characteristics of the sample at the admission hospital are reported in Table 1.

During hospitalization for the transplant procedure, the patients experienced a drop in Hemoglobin (mean 8 g/dL, range 6-13 g/dL) and Platelet levels (30.000/μL, range 7.000-141.000/μL) consistent with what occurs during aplasia.

Throughout the entire duration of the protocol, comprehensive safety monitoring was rigorously conducted, encompassing both the intensive inpatient hospitalization period and subsequent phases.

No hospital readmission for the treatment of post-transplant complications was necessary.

Even during the demanding inpatient hospitalization period, a time often associated with increased fragility, no adverse events (according to CTCAE v5.0) directly attributable to the IRP were recorded.

3.2. Outcome measures

The violation of the assumption of the sphericity was violated for Barthel Index, 6MWT, and MBS (p-value for Mauchly's sphericity test < 0.05), but not for the other outcomes (p-value for Mauchly's sphericity test > 0.05); therefore, for Barthel Index, 6MWT, and MBS findings was used the Greenhouse–Geisser correction.

Table 1
Demographic and clinical characteristics of the included subjects at the hospital admission (N = 47).

Variable	Value
Gender	
Female	26 (55.3%)
Male	21 (44.7%)
Age, *years*	48.2 ± 13.1
Length of stay, *days*	36.9 ± 10.4
Pathology	
AML	31 (66.0%)
ALL	9 (19.1%)
MDS	3 (6.4%)
MF	2 (4.3%)
Aplastic anemia	1 (2.1%)
NHL	1 (2.1%)
Type of transplant	
Haploidentical	14 (29.8%)
HLA-matched sibling donor	10 (21.3%)
MUD	23 (48.9%)
Barthel Index	99.6 ± 2.3
Fatigue Severity Scale	22.6 ± 10.4
30-Second Sit-to-Stand Test	11.7 ± 4.1
Six-min Walking Test, *meters*	424.4 ± 95.6
Modified Borg Scale	1.5 ± 1.4

Abbreviations: AML: Acute Myeloid Leukemia; ALL: Acute Lymphoblastic Leukemia; MDS: Myelodysplastic Syndrome; MF: Myelofibrosis: NHL: Non-Hodgkin Lymphoma; MUD: Mismatched Unrelated Donor.
Notes: Values are presented as frequency (absolute percentage) or mean ± standard deviation.

Regarding the dependence assessed by the BI, the ANOVA did not report any statistically significant difference (p = 0.43) between the assessment times (Fig. 2a).

Findings reported statistically significant differences among the assessments for the fatigue measured by the FSS (p = 0.001). The post-hoc analyses reported statistically significant differences between T1 and T2 (p = 0.009), T2 and T4 (p = 0.026), and T3 and T4 (p = 0.023), but not for the other comparisons (p > 0.05) (Fig. 2b).

Regarding the results of the 6MWT, the ANOVA reported a statistically significant difference (p = 0.007) between the assessment times. Post-hoc tests showed statistically significant differences between T1 and T2 (p = 0.002) and T2 and T4 (p = 0.038), but not for the other comparison (Fig. 2c).

Results reported statistically significant differences among the assessments for the 30STS (p < 0.001). The post-hoc analyses reported statistically significant differences between T1 and T2 (p = 0.007), T1 and T3 (p = 0.001), and T3 and T4 (p = 0.018), but not for the other comparisons (p > 0.05) (Fig. 2d).

Regarding the MBS, the ANOVA reported a statistically significant difference (p = 0.007) between the assessment times. Post-hoc tests showed a difference between T1 and T2 (p = 0.001) and T2 and T4 (p = 0.049), but not for the other comparison (Fig. 2e). Tables with more details on outcome measures are available as supplementary materials.

Mean changes for each assessment comparison with its 95% CI are reported in Table 2.

4. Discussion

As far as we know, no similar protocol has been conducted in Italy. A control group was intentionally omitted in this first phase to prioritize the IRP's safety and its applicability within this specific patient cohort, particularly considering the prevalent fatigue and mobility challenges these patients face due to the numerous potential complications in the immediate post-transplant period. In our work, the sample was homogeneous since all the patients were submitted to the same conditioning regimen, and 66% of them were affected by the same disease (acute myeloid leukemia). The IRP started at hospitalization and was continued

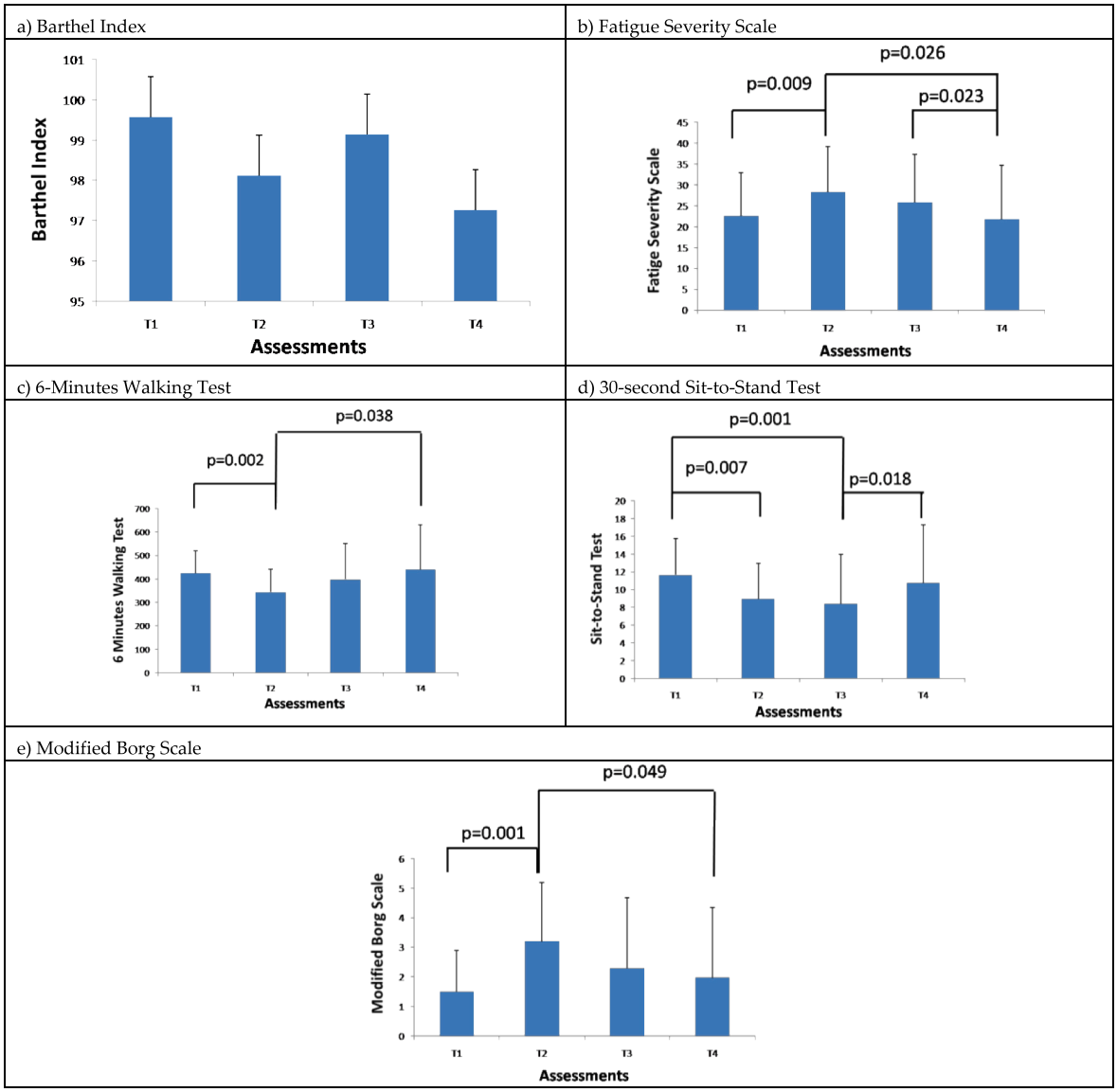


Fig. 2. Graphs illustrating each collected outcome measure for each assessment (T1 = initial assessment; T2 = time of discharge, T3 = 100 days post-transplant; T4 = 6 months post-transplant). The significant comparison are reported with their p-value, while the non-significant comparison are not reported. Six-Minute Walking Test is reported in meters and 30-Second Sit-to-Stand Test is reported as number of repetitions. a) Barthel Index b) Fatigue Severity Scale.

Table 2
Mean change and 95% confidence interval for each point assessment.

Outcome measure	T1-T2	T1-T3	T1-T4	T2-T3	T2-T4	T3-T4
Barthel Index	1.8 (−0.6, 4.1)	2.7 (−0.5, 6.0)	2.6 (−1.4, 6.5)	1.4 (−2.8, 5.6)	1.2 (−3.5, 5.9)	−0.3 (−5.1, 4.4)
Fatigue Severity Scale	−7.0 (−10.2, −3.7)	−7.3 (−12.1, −2.5)	−1.1 (−5.7, 3.6)	0 (−4.1, 4.0)	5.7 (1.5, 9.9)	5.1 (1.4, 8.7)
Six-Minute Walking Test (meters)	85.3 (50.3, 120.3)	44.9 (−16.5, 106.2)	5.2 (−64, 74.4)	−76.1 (−144.0 -8.3)	−117.7 (−195.0 -40.3)	−37.3 (−86, 11.3)
30-Second Sit-to-Stand Test (repetitions)	3.1 (1.7, 4.4)	2.8 (1.1, 4.5)	1.6 (−0.2, 3.4)	−0.3 (−2.1, 1.5)	−1.5 (−3.5, 0.6)	−0.3 (−2.1, 1.5)
Modified Borg Scale	−1.9 (−2.6, −1.1)	−1.4 (−2.3, −0.4)	−0.7 (−1.6, 0.2)	0.9 (−0.4, 2.3)	1.6 (0.5, 2.7)	0.7 (−0.2, 1.6)

until 180 days after transplantation so that the entire time when the most serious complications may occur has been covered.

Given the inherent fragility of this patient cohort, internal dropouts due to death or withdrawal of consent were unavoidable and directly resulted from the severity of their underlying diseases and treatments. However, the proposed IRP appeared feasible, as 100% of the patients who were alive at 180 days completed the study protocol without complications deriving from the training.

No adverse event was reported despite the fact that a portion of the procedure was performed during a critical phase of hospitalization characterized by severe anemia and thrombocytopenia. However, in our study, all patients with hemoglobin levels below 8 g/100 mL received blood transfusions according to standard clinical practice, and rehabilitation sessions were safely postponed until clinical stabilization.

TEs were safely performed across various positions, incorporating both active and passive mobilizations (Baroncini et al., 2024).

The IRP was individualized for each patient, designed considering their specific physical and clinical characteristics that could have an impact on training, such as anemia, low platelets, post-transplant complications and functional deconditioning (Magro et al., 2025; Migliorini et al., 2025). In this context, the collaboration of a multidisciplinary team was essential for designing the most appropriate motor program to adapt to patient's characteristics.

Although this was a preliminary trial primarily aimed at evaluating the feasibility and safety of the IRP procedure, we concurrently aimed to explore whether our protocol produced positive effects on patients, including reduced fatigue and improved post-transplant recovery. To this end, we employed validated scales to objectively quantify these improvements.

In contrast to previous studies that predominantly focused on autologous transplant recipients (Coleman et al., 2003; Dimeo et al., 1997), we opted to focus on allo-HSCT recipients, typically more severely affected by post-transplant complications and necessitating extended hospitalization.

Patients who undergo allo-HSCT experience motor problems related to the original disease, previous pharmacological therapies, or the procedure itself. The main physical complications are myopathy, weakness and muscle hypotrophy. Another common problem is neuropathy, which could lead to weakness, paresthesias, cramps, pain, reduction of tendon reflexes, and secondary damages such as muscle contractures and joint deformities (Golec et al., 2019; New-Tolley et al., 2018; Kraus et al., 2012). However, neuropathy and its potential contribution to functional performance were not systematically assessed in the present cohort. It is also demonstrated that bed rest in the first week causes a loss of muscle strength of 20-30%, a decrease in cardiac volume of 10% after nine days and an increase in resting heart rate of 22% after about four weeks (Hung et al., 1983; Booth et al., 2012; Topp et al., 2002). Allo-HSCT patients are forced, during the period of aplasia, to a prolonged isolation regime during which a significant reduction in physical activity seems related to fatigue onset (Abdalrahman et al., 2022; Hacker et al., 2006).

Recently, some authors started focusing on allo-HSCT. Still, the protocol applied in the trial mainly involved the post-discharge phase, thus starting from a function most impaired by hospitalization (Mello et al., 2003). In 2009, a randomized study demonstrated significant improvements in endurance, strength and QoL in patients undergoing a motor program from the beginning of hospitalization, compared with the control group (Baumann et al., 2010).

The subject is so debated that several reviews have been carried out. The most recent evaluated 25 studies that assessed the effects of TEs on patients undergoing HSCT. This review highlighted the safety and benefits of this intervention, both from a cardiovascular point of view and in terms of strength and mobility, even though it was burdened by limitations such as the heterogeneity of the hematological diseases considered, the conditioning and the TEs performed, and often the short follow up (Morales-Rodriguez et al., 2022).

Our results showed a significant improvement of all the considered parameters at the fourth time point 180 days after allo-HSCT, thus corroborating the efficacy of the proposed protocol in preserving physical and functional capacity, mitigating fatigue, and promoting gradual recovery in patients, supporting the existing literature (Takekiyo and Morishita, 2023; Takekiyo et al., 2016).

As expected, the decline in the initial functional status at discharge and after 100 days was compatible with the fact that the first period is burdened by the most serious complications such as infections, veno-occlusive disease and graft versus host disease (GVHD).

Fatigue perception significantly increased immediately after transplantation and impacted QoL throughout the period between discharge and 100 days post-transplant. Moreover, physical and functional capacity deteriorated significantly in the first 100 days post-transplant. These results are in line with existing literature (Takekiyo et al., 2016; Filgueira et al., 2023; Palmer et al., 2019).

Also, as noticed in a previous study, 6MWT showed significant worsening after allo-HSCT, possibly reflecting the decline in physical function due to bed confinement (Morishita et al., 2015).

The analysis of mean changes between assessment points adds critical insight into the temporal dynamics and clinical relevance of functional recovery in our population. Notably, FSS showed a significant increase in fatigue from baseline to follow-up. Similarly, the 6MWT revealed a substantial initial decline in functional capacity post-transplant, followed by progressive recovery at later time points. The positive mean change between T2 and T4 (117.7 m) suggests the effectiveness of the IRP in restoring functional aerobic capacity. The decline in 30STS performance indicates reduced capacity to perform repeated sit-to-stand transfers; it does not, however, establish whether this change was driven by muscle weakness, fatigue, impaired balance, or other factors. Importantly, the MBS scores increased significantly from T1 to T2, reflecting higher perceived exertion and lower tolerance. BI exhibited only minor mean changes between time points, corroborating the ANOVA findings and suggesting that basic functional independence was largely preserved throughout the study period. Thus, the mean change data highlight the acute impact of allo-HSCT and its complications on physical performance and fatigue, as well as the potential for substantial recovery with an adequate IRP. The temporal patterns observed (i.e. marked early decline followed by significant improvement at later follow-ups) emphasize the importance of sustained TE interventions both during hospitalization and after discharge. These results reinforce the need for comprehensive, phase-specific rehabilitation strategies to optimize functional outcomes and QoL in this population.

It is noteworthy that in this patient population, the BI applicability may be limited (Manocchio et al., 2025). Despite experiencing significant physical decline, these patients often maintain a high degree of autonomy and independence in their ADLs, as assessed by the BI. The observed dissociation between profound fatigue and the sustained level of functional independence underscores the resilience of this patient population. Patients often prioritize and conserve their limited energy resources to complete essential tasks that maintain autonomy, thereby facilitating hospital discharge.

Caregivers or family members were not assigned a standardized role or included in a structured training component, and their actual involvement was not recorded systematically. Basic activities of daily living remained largely preserved according to the Barthel Index, which supported a patient-directed approach in this cohort; nevertheless, this finding does not exclude a potential contribution from family or caregivers at home.

Given the cumulative toxic burden experienced by hematological patients undergoing transplantation, a future direction could be conducting a comprehensive patient assessment and developing an IRP already several weeks before the procedure, with the aim of enhancing the patient's mobility and strength levels prior to the procedure mitigating the risk of significant post-transplant functional decline.

Our current study, focused on the safety and feasibility of this approach, provides crucial foundational data for designing a subsequent randomized controlled trial (RCT). The initial feasibility outcomes, particularly concerning patient compliance, recruitment rates, and adherence to the protocol, will be essential for setting realistic enrollment targets and ensuring the future trial is adequately powered. Moreover, the safety profile established will directly inform the primary safety endpoints and necessary monitoring strategies for the phase of the RCT, allowing us to proceed with a refined and optimized study design.

4.1. Limitations of the study

This preliminary study has some inherent limitations. The relatively small sample size limits the statistical power, and the design (i.e., not RCT) with the absence of a control group makes it challenging to definitively attribute observed patient improvements solely to the

intervention, as natural recovery could also play a significant role. While rehabilitation (i.e. TE for motor impairments) has already been validated as beneficial for endurance, strength, and independence in ADLs (Santana-Sosa et al., 2008) and physiological systems (e.g. in the hematopoietic system, by accelerating cell recovery) (Beller et al., 2021) our results regarding the effects have to be cautiously interpreted in consideration of the absence of a control group. However, a prior study by Kim et al. (2025), despite lacking a control group, similarly demonstrated both the feasibility and safety of rehabilitation, specifically telerehabilitation, within this patient population. Importantly, that study also reported the presence of genuinely positive effects, reinforcing the potential benefits of such interventions even without the rigorous comparative design of a RCT. This accumulating evidence suggests that initial positive findings in this delicate cohort may be reliably observed even in preliminary, uncontrolled settings.

Another limitation was that the assessor was not blinded to the study's purpose or the patients' interventions, which could have biased the results. We tried to mitigate this by employing validated patients reported outcomes (i.e. FSS, MBS) and objective measurements (i.e. 6MWT, 30STS) in which the influence of the assessor is minimal. Moreover, the collaboration between the PRM specialist and the PT was helpful in reducing possible results' alterations.

The heterogeneity of TE interventions (e.g., different types, frequency, intensity, type of session, volume of session, type of supervision) may have had an impact on the recovery of patients. However, individualization of the interventions in the context of PRM is crucial, as stated by the PRM Section and Board of the European Union of Medical Specialists (UEMS) in Europe (Zampolini et al., 2022). Consistently with the UEMS-PRM perspective, we operationalized the IRP through joint PRM–Hematology assessment and goal-setting, individualized selection and progression of TE components, monitoring of adherence and safety across inpatient and post-discharge phases and documentation suitable for continuity of care. The selection of exercise domains (i.e. respiratory function, joint mobility, muscle strength and endurance, balance/-coordination, flexibility, and graded ambulation) reflects both UEMS-PRM emphasis on function-oriented targets and the unit's established workflows, personnel skill mix, and safety constraints specific to allo-HSCT (e.g., aplasia, anemia, thrombocytopenia, infection control).

Furthermore, data on social support for TE training or the patients' home environments were not systematically collected. Home-based exercise was not supervised or independently monitored, and the available self-report records did not allow us to quantify exercise frequency reliably across the post-discharge period. We also did not systematically document caregiver involvement or use a formal goal-attainment measure to assess individual long-term rehabilitation goals. These limitations restrict the interpretation of post-discharge adherence and the extent to which the IRP met patient-specific goals.

Another issue was that not every patient underwent the same complications after allo-HSCT, and especially those who did steroid therapy for GVHD may have experienced a worse decline in physical function than others (Morishita et al., 2013; Cantò et al., 2026). However, it is noteworthy that no patient required hospital readmission specifically for the management or treatment of any post-transplant complication. Lastly, alternative or complementary measures of functional independence (such as WHO Disability Assessment Schedule - WHODAS 2.0), might be applied in future work considering the limited sensitivity of BI in this setting.

5. Conclusions

While advancements in allo-HSCT have led to improved survival rates, there remains a need to enhance QoL post-transplantation.

Our preliminary prospective study revealed the feasibility and safety of the proposed IRP within a particularly vulnerable patient cohort susceptible to numerous complications. Furthermore, it indicated significantly positive effects on post-transplant recovery, findings that warrant definitive validation through a prospective RCT to robustly ascertain efficacy and to develop targeted interventions that could be integrated into routine care.

CRediT authorship contribution statement

N. Manocchio: Writing – review & editing, Conceptualization. **E. Buzzatti:** Writing – review & editing, Conceptualization. **C. Scarpini:** Investigation, Data curation, Conceptualization. **A. D'Amato:** Writing – original draft. **C. Ljoka:** Writing – original draft. **L. Pellicciari:** Formal analysis. **F. De Nicola:** Writing – original draft, Investigation. **G. De Angelis:** Investigation. **B. Mariotti:** Investigation. **G. Ciangola:** Investigation. **R. Cerretti:** Methodology, Investigation. **M.I. Del Principe:** Writing – review & editing, Methodology. **A. Venditti:** Supervision, Methodology. **C. Foti:** Supervision, Methodology.

Informed consent statement

Written informed consent for the procedures performed, participation in this study, and publication of the case details was obtained from the patients. In accordance with the Journal of Bodywork and Movement Therapies author guidelines ("Written consents must be retained. They should not be provided to this journal unless this is specifically requested in exceptional circumstances, for example, when a legal issue arises. Only then should you provide copies of the consents, or evidence that all relevant consents were obtained."), the consent form is held by the authors and available upon request.

Ethical approval

The clinical protocol was conducted, recorded and reported in accordance with Good Clinical Practice guidelines and Declaration of Helsinki. All patients were asked to sign an informed consent form before taking part in the study. The study was approved by the Lazio Area 2 Ethical Committee (233.22).

Author disclosures

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Declaration of competing interest

Authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbmt.2026.10.001.

References

Abdalrahman, O.A., Othman, E.H., Khalifeh, A.H., Suleiman, K.H., 2022. Fatigue among post–hematopoietic stem cell transplant patients in Jordan: prevalence and associated factors. Support. Care Cancer 30, 7679–7687. https://doi.org/10.1007/s00520-022-07186-0.

ATS Statement, 2002. Guidelines for the six-minute walk test. Am. J. Respir. Crit. Care Med. 166, 111–117. https://doi.org/10.1164/ajrccm.166.1.at1102.

Baguley, B., Bolam, K., Wright, O., Skinner, T., 2017. The effect of nutrition therapy and exercise on cancer-related fatigue and quality of life in men with prostate cancer: a systematic review. Nutrients 9, 1003. https://doi.org/10.3390/nu9091003.

Baroncini, A., Maffulli, N., Schäfer, L., Manocchio, N., Bossa, M., Foti, C., Klimuch, A., Migliorini, F., 2024. Physiotherapeutic and non-conventional approaches in patients with chronic low-back pain: a level I bayesian network meta-analysis. Sci. Rep. 14, 11546. https://doi.org/10.1038/s41598-024-62276-9.

Baumann, F.T., Kraut, L., Schüle, K., Bloch, W., Fauser, A.A., 2010. A controlled randomized study examining the effects of exercise therapy on patients undergoing haematopoietic stem cell transplantation. Bone Marrow Transplant 45, 355–362. https://doi.org/10.1038/bmt.2009.163.

Beller, R., Bennstein, S.B., Götte, M., 2021. Effects of exercise interventions on immune function in children and adolescents with cancer and HSCT recipients - a systematic review. Front. Immunol. 12, 746171. https://doi.org/10.3389/fimmu.2021.746171. PMID: 34646274; PMCID: PMC8504856.

Booth, F.W., Roberts, C.K., Laye, M.J., 2012. Lack of exercise is a major cause of chronic diseases. Compr. Physiol. 2, 1143–1211. https://doi.org/10.1002/cphy.c110025.

Borg, G.A., 1982. Psychophysical bases of perceived exertion. Med. Sci. Sports Exerc. 14, 377–381.

Bruera, E., Yennurajalingam, S., 2010. Challenge of managing cancer-related fatigue. J. Clin. Oncol. 28, 3671–3672. https://doi.org/10.1200/JCO.2010.29.8984.

Cantò, P.A., Montoro, J., Balaguer-Roselló, A., Villalba, M., Chorão, P., Louro, A., Granados, P., Eirís, J., Bataller, A., Gómez-Seguí, I., Solves, P., León, G., Lamas, B., Eritzpokhoff, L., Vallejo, N., Hervás, A., Hurtado, M., López, J., Mansilla-Polo, M., Reig, J.P., Valero, M.G.G., De la Rubia, M., Satorres, C., De la Rubia, J., Sanz, M.A., Sanz, J., 2026. Chronic graft-*versus*-host disease in the era of posttransplant cyclophosphamide. Haematologica 111 (7), 2366–2376. https://doi.org/10.3324/haematol.2025.289266. Epub 2026 Jan 22. PMID: 41568541; PMCID: PMC13317873.

Coleman, E.A., Coon, S., Hall-Barrow, J., Richards, K., Gaylor, D., Stewart, B., 2003. Feasibility of exercise during treatment for multiple myeloma. Cancer Nurs. 26, 410–419. https://doi.org/10.1097/00002820-200310000-00012.

Cramp, F., Byron-Daniel, J., 2012. Exercise for the management of cancer-related fatigue in adults. Cochrane Database Syst. Rev. 2021. https://doi.org/10.1002/14651858.CD006145.pub3.

Dimeo, F., Fetscher, S., Lange, W., Mertelsmann, R., Keul, J., 1997. Effects of aerobic exercise on the physical performance and incidence of treatment-related complications after high-dose chemotherapy. Blood 90, 3390–3394.

Eid, M., Alkerdasy, H., Metwally, M., Abdelwahab, E.M., Batalik, L., 2026. Home-based, telehealth, and hybrid exercise interventions for adults undergoing or recovering from hematopoietic stem cell transplantation: a systematic review of randomized controlled trials. Front. Rehabil. Sci. 7, 1846935. https://doi.org/10.3389/fresc.2026.1846935.

Enright, P.L., 2003. The six-minute walk test. Respir. Care 48, 783–785.

Filgueira, L., Steinberg, A., Mendonca, R., Lim, S.H., 2023. Returning to employment following allogeneic hematopoietic stem cell transplant: a major problem among survivors. eJHaem 4, 1132–1142. https://doi.org/10.1002/jha2.788.

Galeoto, G., Sansoni, J., Valenti, D., 2018. The effect of physiotherapy on fatigue and physical functioning in chronic fatigue syndrome patients: a systematic review. Clin. Ter. 184–188. https://doi.org/10.7417/T.2018.2076.

Golec, S., Rabinovich, E., Cohen, M., Baer, L., Chamoun, K., Lima, M., 2019. Refractory Inflammatory Myopathy in Hematopoietic Stem Cell Transplant Patients with Chronic Graft-versus-Host Disease: report of Two Cases. Hematol. Transfus. Cell Ther 41, 268–271. https://doi.org/10.1016/j.htct.2019.01.002.

Hacker, E.D., Ferrans, C., Verlen, E., Ravandi, F., Van Besien, K., Gelms, J., Dieterle, N., 2006. Fatigue and physical activity in patients undergoing hematopoietic stem cell transplant. Oncol. Nurs. Forum 33, 614–624. https://doi.org/10.1188/06.ONF.614-624.

Hematopoietic Stem Cell Transplantation, 2009. In: Bishop, M.R. (Ed.), Cancer Treatment and Research, 144. Springer US, Boston, MA, ISBN 978-0-387-78579-0.

Hung, J., Goldwater, D., Convertino, V.A., McKillop, J.H., Goris, M.L., DeBusk, R.F., 1983. Mechanisms for decreased exercise capacity after bed rest in normal middle-aged men. Am. J. Cardiol. 51, 344–348. https://doi.org/10.1016/S0002-9149(83)80063-0.

Jones, C.J., Rikli, R.E., Beam, W.C., 1999. A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. Res. Q. Exerc. Sport 70, 113–119. https://doi.org/10.1080/02701367.1999.10608028.

Kim, D.Y., Choi, J., Kim, C.R., Lee, Y., Kim, Y., Jo, J.C., 2025. Feasibility and effects of the telerehabilitation program during hematopoietic stem cell transplantation. Medicine (Baltim.) 104 (8), e41591. https://doi.org/10.1097/MD.0000000000041591. PMID: 39993090; PMCID: PMC11856893.

Kraus, P.D., Wolff, D., Grauer, O., Angstwurm, K., Jarius, S., Wandinger, K.P., Holler, E., Schulte-Mattler, W., Kleiter, I., 2012. Muscle cramps and neuropathies in patients with allogeneic hematopoietic stem cell transplantation and graft-versus-host disease. PLoS One 7, e44922. https://doi.org/10.1371/journal.pone.0044922.

Krupp, L.B., 1989. The fatigue severity scale: application to patients with multiple sclerosis and systemic lupus erythematosus. Arch. Neurol. 46, 1121. https://doi.org/10.1001/archneur.1989.00520460115022.

Kurosawa, S., Yamaguchi, T., Mori, T., Kanamori, H., Onishi, Y., Emi, N., Fujisawa, S., Kohno, A., Nakaseko, C., Saito, B., et al., 2015. Patient-reported quality of life after allogeneic hematopoietic cell transplantation or chemotherapy for acute leukemia. Bone Marrow Transplant 50, 1241–1249. https://doi.org/10.1038/bmt.2015.137.

Magro, V.M., Sorbino, A., Manocchio, N., Ljoka, C., Foti, C., 2025. The physiatrist in intensive care: Role, tasks, and critical issues in a clinical case report analysis. Clin. Transl. Neurosci 9, 11. https://doi.org/10.3390/ctn9010011.

Mañas-García, L., Penedo-Vázquez, A., López-Postigo, A., Deschrevel, J., Durán, X., Barreiro, E., 2020. Prolonged immobilization exacerbates the loss of muscle mass and function induced by cancer-associated Cachexia through enhanced proteolysis in mice. Int. J. Mol. Sci. 21, 8167. https://doi.org/10.3390/ijms21218167.

Manocchio, N., Ljoka, C., Ferdinandi, V., Cicchi, L., Foti, C., 2025. Commentary on "The Learning Rehabilitation System: strengthening an Intersectoral Strategy to Improve Functioning of an Ageing Population" by Bickenbach et Al. Health Policy 155, 105303. https://doi.org/10.1016/j.healthpol.2025.105303.

Mavrov, M., 2018. The Law Institute of Patient's Informed Consent. Publ. House Stovi Group Bulg., pp. 17–18

Mello, M., Tanaka, C., Dulley, F.L., 2003. Effects of an Exercise Program on muscle performance in patients undergoing allogeneic bone marrow transplantation. Bone Marrow Transplant 32, 723–728. https://doi.org/10.1038/sj.bmt.1704227.

Migliorini, F., Maffulli, N., Schäfer, L., Manocchio, N., Bossa, M., Foti, C., Betsch, M., Kubach, J., 2025. Impact of education in patients undergoing physiotherapy for lower back pain: a level I systematic review and meta-analysis. Eur. J. Trauma Emerg. Surg. 51, 113. https://doi.org/10.1007/s00068-025-02788-9.

Mitchell, S.A., Hoffman, A.J., Clark, J.C., DeGennaro, R.M., Poirier, P., Robinson, C.B., Weisbrod, B.L., 2014. Putting evidence into practice: an update of evidence-based interventions for cancer-related fatigue during and following treatment. Clin. J. Oncol. Nurs. 18, 38–58. https://doi.org/10.1188/14.CJON.S3.38-58.

Mohammed, J., Aljurf, M., Althumayri, A., Almansour, M., Alghamdi, A., Hamidieh, A. A., ElHaddad, A., Othman, T.B., Bazarbachi, A., Almohareb, F., et al., 2019. Physical therapy pathway and protocol for patients undergoing hematopoietic stem cell transplantation: recommendations from the Eastern mediterranean blood and marrow transplantation (EMBMT) group. Hematol. Oncol. Stem Cell Ther 12, 127–132. https://doi.org/10.1016/j.hemonc.2018.12.003.

Morales-Rodriguez, E., Pérez-Bilbao, T., San Juan, A.F., Calvo, J.L., 2022. Effects of exercise programs on physical factors and safety in adult patients with cancer and haematopoietic stem cell transplantation: a systematic review. Int. J. Environ. Res. Public. Health 19, 1288. https://doi.org/10.3390/ijerph19031288.

Morishita, S., Kaida, K., Aoki, O., Yamauchi, S., Wakasugi, T., Ikegame, K., Ogawa, H., Domen, K., 2015. Balance function in patients who had undergone allogeneic hematopoietic stem cell transplantation. Gait Posture 42, 406–408.

Morishita, S., Kaida, K., Yamauchi, S., Sota, K., Ishii, S., Ikegame, K., Kodama, N., Ogawa, H., Domen, K., 2013. Relationship between corticosteroid dose and declines in physical function among allogeneic hematopoietic stem cell transplantation patients. Support. Care Cancer 21, 2161–2169. https://doi.org/10.1007/s00520-013-1778-7.

Morishita, S., Tsubaki, A., Hotta, K., Fu, J.B., Fuji, S., 2019. The benefit of exercise in patients who undergo allogeneic hematopoietic stem cell transplantation. J Int Soc Phys Rehabil Med 2 (1), 54–61. https://doi.org/10.4103/jisprm.jisprm_2_19. Epub 2019 May 22. PMID: 31131374; PMCID: PMC6532661.

New-Tolley, J., Smith, C., Koszyca, B., Otto, S., Maundrell, A., Bardy, P., Hiwase, D., Yong, A.S.M., Lewis, I., Limaye, V., 2018. Inflammatory myopathies after allogeneic stem cell transplantation. Muscle Nerve 58, 790–795. https://doi.org/10.1002/mus.26341.

Palmer, J., Kosiorek, H.E., Wolschke, C., Fauble, V.D.S., Butterfield, R., Geyer, H., Scherber, R.M., Dueck, A.C., Gathany, A., Mesa, R.A., et al., 2019. Assessment of quality of life following allogeneic stem cell transplant for myelofibrosis. Biol. Blood Marrow Transplant 25, 2267–2273. https://doi.org/10.1016/j.bbmt.2019.07.001.

Parry, S.M., Puthucheary, Z.A., 2015. The impact of extended bed rest on the musculoskeletal System in the critical care environment. Extreme Physiol. Med. 4, 16. https://doi.org/10.1186/s13728-015-0036-7.

Pearson, E.J.M., Morris, M.E., Di Stefano, M., McKinstry, C.E., 2018. Interventions for cancer-related fatigue: a scoping review. Eur. J. Cancer Care (Engl.) 27, e12516. https://doi.org/10.1111/ecc.12516.

Pérez-Aguilar, R., Pérez-Simón, J.A., Pabón-Carrasco, M., Pinero-Pinto, E., 2026. Feasibility and safety of physical rehabilitation interventions in oncohematologic patients following allogeneic hematopoietic stem cell transplantation: a systematic review and meta-analysis. Transplant Cell Ther 32 (7), 815–831. https://doi.org/10.1016/j.jtct.2026.03.021. Epub 2026 Mar 20. PMID: 41864575.

Persoon, S., Kersten, M.J., Van Der Weiden, K., Buffart, L.M., Nollet, F., Brug, J., Chinapaw, M.J.M., 2013. Effects of exercise in patients treated with stem cell transplantation for a hematologic malignancy: a systematic review and meta-analysis. Cancer Treat. Rev. 39, 682–690. https://doi.org/10.1016/j.ctrv.2013.01.001.

Robinson, P.D., Oberoi, S., Tomlinson, D., Duong, N., Davis, H., Cataudella, D., Culos-Reed, N., Gibson, F., Götte, M., Hinds, P., et al., 2018. Management of fatigue in children and adolescents with cancer and in paediatric recipients of haemopoietic stem-cell transplants: a clinical practice guideline. Lancet child adolesc. Health 2, 371–378. https://doi.org/10.1016/S2352-4642(18)30059-2.

Santana-Sosa, E., Barriopedro, M.I., López-Mojares, L.M., Pérez, M., Lucia, A., 2008. Exercise training is beneficial for Alzheimer's patients. Int J Sports Med 29 (10), 845–850. https://doi.org/10.1055/s-2008-1038432. Epub 2008 Apr 9. PMID: 18401810.

Steinberg, A., Asher, A., Bailey, C., Fu, J.B., 2015. The role of physical rehabilitation in stem cell transplantation patients. Support. Care Cancer 23, 2447–2460. https://doi.org/10.1007/s00520-015-2744-3.

Takekiyo, T., Dozono, K., Mitsuishi, T., Nara, S., Yoshida, K., Murayama, Y., Maeda, A., Chaen, T., Nakano, N., Kubota, A., et al., 2016. Recovery of physical function and quality of life in patients undergoing hematopoietic stem cell transplantation: a 1-Year Follow-Up. Bone Marrow Transplant 51, 1127–1130. https://doi.org/10.1038/bmt.2016.58.

Takekiyo, T., Morishita, S., 2023. Effect of rehabilitation in patients undergoing hematopoietic stem cell transplantation. Fukushima J. Med. Sci. 69, 73–83. https://doi.org/10.5387/fms.2022-33.

Topp, R., Ditmyer, M., King, K., Doherty, K., Hornyak, J., 2002. The effect of bed rest and potential of prehabilitation on patients in the intensive care unit: AACN Clin. Issues

adv. Pract. Acute crit. Care 13, 263–276. https://doi.org/10.1097/00044067-200205000-00011.
Wade, D.T., Collin, C., 1988. The Barthel ADL index: a standard measure of physical disability? Int. Disabil. Stud. 10, 64–67. https://doi.org/10.3109/09638288809164105.
Wiskemann, J., Huber, G., 2008. Physical exercise as adjuvant therapy for patients undergoing hematopoietic stem cell transplantation. Bone Marrow Transplant 41, 321–329. https://doi.org/10.1038/sj.bmt.1705917.
World Medical Association Declaration of Helsinki, 2013. Ethical principles for medical research involving human subjects. JAMA 310, 2191. https://doi.org/10.1001/jama.2013.281053.
Zampolini, M., Selb, M., Boldrini, P., Branco, C.A., Golyk, V., Hu, X., Kiekens, C., Negrini, S., Nulle, A., et al., 2022. The individual rehabilitation Project as the core of person-centered rehabilitation: the physical and rehabilitation medicine section and board of the European Union of Medical specialists framework for rehabilitation in Europe. Eur J Phys Rehabil Med 58. https://doi.org/10.23736/S1973-9087.22.07402-0.