



LONG-TERM FOLLOW-UP OF USE OF THERAPY SERVICES FOR PATIENTS WITH MODERATE-TO-SEVERE TRAUMATIC BRAIN INJURY

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Objectives: To examine the probabilities and baseline predictors of the use of physical therapy, occupational therapy and speech therapy over a period of 10 years after traumatic brain injury.

Design: Longitudinal prospective follow-up at 1, 2, 5 and 10 years after traumatic brain injury.

Participants: A total of 97 patients with moderate-to-severe traumatic brain injury recruited from Oslo University Hospital, Norway, during acute hospital admission in 2005–2007.

Methods: Socio-demographics and injury characteristics were recorded at baseline. Use of physical therapy, occupational therapy and speech therapy were recorded at follow-ups. Hierarchical linear modelling was applied to examine service use probabilities across the 4 time-points.

Results: Service use decreased substantially over time, with physical therapy being the main service utilized at the 10-year follow-up (physical therapy 16%, occupational therapy 1%, speech therapy 3%). Use of services was related to severity of injury (CT head severity scores and post-traumatic amnesia), female sex, and pre-injury employment. In addition, in this sample, time since injury was associated with use of occupational therapy and speech therapy.

Conclusion: This study presents a novel model for the long-term probability of use of physical therapy, occupational therapy and speech therapy following traumatic brain injury. The use of services was much lower than the expected problem profile of severe traumatic brain injuries, suggesting an insufficient long-term provision of traditional traumatic brain injury rehabilitation services.

Key words: traumatic brain injury; rehabilitation; health services; longitudinal study; physical therapy; occupational therapy; speech therapy.

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Traumatic brain injuries (TBIs) are a leading cause of disability worldwide and impose a heavy societal burden due to the healthcare costs involved. The

LAY ABSTRACT

Long-term disabilities are common after traumatic brain injury. Consequently, many patients need healthcare services following injury. This study followed 97 individuals with traumatic brain injury until 10 years after injury, and found that the use of physical therapy, occupational therapy and speech therapy decreased substantially over time. Approximately 1 in 6 individuals used physical therapy at 10 years, whereas the use of occupational and speech therapy was much lower. Higher use of services was associated with more severe injury, female sex, and being employed before injury. The low level of service use at 10 years after injury might indicate unmet needs in this patient population.

consequences of TBI are often related to severity of injury (1–4), and affect patients' physical, cognitive and emotional functioning (5–7). Thus, individuals with TBI may require a wide range of rehabilitation services delivered by healthcare professionals (8, 9). The traditional rehabilitation services include physical therapy (PT), occupational therapy (OT) and speech therapy (ST). PT plays an important role in physical recovery, and enables patients to become as mobile and independent as possible. OT is essential in improving the ability to perform daily tasks, such as dressing, washing, cooking and leisure activities, cognitive functioning and adaptation in the home environment, and returning to work. ST helps patients to improve their communication skills, as well as disturbances in eating or swallowing. These services are frequently applied in the acute/sub-acute phases of moderate-to-severe TBI. Phillips et al. found that traditional rehabilitation services were far more likely to be used than psychological counselling at discharge 3 months post-TBI (9). Similarly, Jourdan et al. reported that 78% of patients received PT, 61% ST and 50% OT following discharge from acute care after severe TBI (8).

Studies have highlighted the importance of timely access to appropriate TBI care (10, 11). With the shift toward viewing TBI as a dynamic, chronic health condition, it is increasingly accepted that more health services are needed to address long-term healthcare needs (12). However, knowledge of the long-term use of PT, OT and ST, and their associations with personal and injury

severity characteristics is still sparse. A French study reported that 18% of patients received PT, 15% ST, and only 1% OT 4 years after severe TBI (8). Other studies have found that service provision was significantly associated with injury severity and motor, speech, and psychological impairments, but not with cognitive impairments (13, 14). An Australian study reported that 14% of individuals with TBI used PT, 3% OT, and 3% ST 10–17 years post-injury (13). Studies determining the predictive value of socio-demographics on use of PT, OT and ST services show contradictory results. Some studies have reported sex differences in service provision, such as higher healthcare use in females (15). In other studies, males received more services (16), or sex was not related to service provision (8, 9). Furthermore, some studies reported that younger individuals with TBI more often received rehabilitation (8, 15–17), while others reported that older aged individuals received more rehabilitation services (16, 18, 19).

Johnstone et al. reported that environmental factors, such as urban and rural geographical regions, may influence access to TBI rehabilitation services, and that services offered in the long-term are often inadequate (20). The service provision level may depend on the healthcare system (17, 21, 22). To shed light on this topic, studies from different healthcare systems are required. No prior longitudinal studies from Nordic countries (Norway, Sweden, Denmark, Finland, and Iceland) have examined the probability of use of rehabilitation services over a decade post-TBI. Such studies may be of international interest in order to plan service organization and resource allocation within the healthcare systems.

The aims of this study were to examine the probabilities of longitudinal service use of PT, OT and ST, and to assess injury severity-related and sociodemographic factors as predictors of their use at 1, 2, 5 and 10 years post-injury. It was hypothesized that the probability of service use would decrease substantially from 1 to 10 years post-injury, and would relate to the severity of injury, younger age, female sex, functional level and time since injury.

METHODS

Participants

Participants were from a cohort study of patients with acute TBI who were admitted to the Trauma Referral Centre in South Eastern Norway during the period 2005–2007. The inclusion criteria for the original study were: (i) age range 16–55 years; (ii) admitted with ICD-10 diagnoses of S06.0–S06.9 within 24 h of injury; (iii) admitted with a Glasgow Coma Scale (GCS) score (23) of 3–12, representing moderate-to-severe TBI, at admission or before intubation; and (iv) residence in Eastern Norway. The exclusion criteria were: (i) previously known neurological disorder; (ii) associated spinal cord injuries; (iii) previous diagnosis of severe psychiatric disorder or substance abuse disorders; and (iv) unknown address or incarceration at the time of admission.

The first 3 exclusion criteria involve conditions that may result in persistent sequela, which may influence TBI outcome assessment; hence these patients were excluded from the study. All patients underwent a baseline assessment in the acute phase, and received follow-up after 1, 2, 5 and 10 years (24, 25).

Of the original 133 patients who were recruited, 32 died during the acute or post-acute phase, and 4 withdrew before 1-year follow-up, leaving 97 patients at the 1-year follow-up. From 1- to 2-year follow-ups, 92 patients continued to be followed up (4 dropped out and 1 had missing data for the service use); from 2- to 5-year follow-ups 89 patients were included (3 dropped out); and from 5- to 10-year follow-ups 74 patients participated through the final follow-up (12 dropped out and 4 had missing data). The hierarchical linear models retained all individuals with a full data-set at 1-year follow-up through use of full information maximum likelihood estimation.

Procedure

Admission and injury-related variables were extracted from the medical records. Assessments at the 1-, 2-, 5- and 10-year follow-ups were mainly performed by a physiatrist at the outpatient department. In some instances, upon request from participants, the assessments were completed by an ambulatory team or via a phone interview. The relatives of severely injured patients participated in the follow-up and verified the use of services.

Ethics

The study was carried out in accordance with the Norwegian law on research ethics and medical research. Ethical approval to conduct this study was granted by the Regional Committee for Medical and Health Research Ethics, East Norway, and the Norwegian Data Inspectorate. All individuals provided written informed consent to participate in the study.

Measures

The dependent variables were the proportions of PT, OT and ST use at 1, 2, 5 and 10 years post-injury. These data were collected during follow-up interviews with patients. Patients were asked if the respective services were used for TBI during the last 1–3 months (yes vs no). Independent (predictor) variables recorded in the medical records and/or in the hospital's Trauma Registry were: age at time of injury, sex (male vs female), relationship status at admission (partnered vs single), educational level (in years), employment status at injury (employed vs unemployed), occupational status at admission (blue-collar (physical) vs white-collar (non-physical)), cause of injury (traffic accident vs other), acute GCS score (ranges 3–12, with 3–8 and 9–12 considered as severe and moderate injuries), duration of post-traumatic amnesia (PTA) (number of days), Injury Severity Score (ISS) (26) (ranges 1–75, from best to worst), and CT severity score categorized according to the Marshall CT classification (27). Global function was assessed by the 8-level Glasgow Outcome Scale Extended (GOSE) (28). For the purpose of this study, GOSE was dichotomized to the unfavourable group (i.e. severe disability and lower level of moderate disability, score 3–5) and favourable (i.e. upper level of moderate disability and good recovery, score 6–8) outcome groups. Functioning in activities of daily living (ADL) was measured by the Functional Independence Measure (FIM) (29) Motor and Cognitive domain at 1- and 5-year follow-ups. In the present study, the FIM-Motor (score range 13–91, worst-to-best) and FIM-Cognitive (score range 5–35, worst-to-best) variables were dichotomized at the cut-off for being dependent/independent in ADL (score 78 and 30, respectively).

Statistical analysis

Descriptive statistics were used to present demographics and injury-related variables. Results are presented as percentages, means with standard deviations (SD) or median and interquartile range (IQR), as appropriate. χ^2 analyses were performed in the case of categorical variables and for frequency of service utilization across the follow-ups. Hierarchical linear modelling (HLM) was used to examine baseline predictors of probability trajectories of physical therapy use, occupational therapy use, and speech therapy use across 1, 2, 5 and 10 years after injury. Three conditional (null) models were run first on each type of therapy service use, to determine whether there was sufficiently large clustering of therapy use probability variance within participants to proceed with HLM. Unconditional growth linear, quadratic and cubic models were then run with no predictors to determine the most accurate model for linear or polynomial architecture of the 3 types of therapy use probabilities over time.

Once the most accurate curvature models were identified for each type of therapy service use probabilities, predictors were entered simultaneously as fixed effects into 3 separate HLMs (1 for each type of therapy use) after being centred or given a reference point of 0, along with time (or appropriate multiplicatives of time when polynomial trends were found). For each type of therapy use, the first full model used HLM to determine whether trajectories of therapy use probabilities across the 4 time-points could be predicted by: Time (coded as 0 (1 year), 1 (2 years), 4 (5 years), or 9 (10 years) to reflect actual spacing between time-points; and multiplicatives of time, as appropriate), sex (1=female, 0=male), age, relationship status (1=partnered, 0=single), education, employment at admission (1=employed, 0=unemployed), occupational status (1=white-collar, 0=blue-collar), GCS score, cause of injury (1=motor vehicle, 0=not motor vehicle), length of PTA (days), CT severity score, and ISS. A second HLM for each type of therapy use included the previously significant predictors from the first full model, time (and multiplicatives of time, as appropriate), and the interaction terms between time (and multiplicatives of time, as appropriate) and the previously significant predictors.

RESULTS

Demographics, injury-related characteristics and functioning

The mean age of the 97 patients at the time of injury was 30.3 (SD 10.8) years, 76% were men, 60% were injured in road traffic accidents, and 45% were substance influenced at the time of injury. The mean GCS at hospital admission was 7.2 (SD 3.2), and 29% underwent intracranial surgery. Of the total sample, only 31% had isolated TBI without associated injuries. In the group TBI with associated injuries, 79% had injuries in several regions (i.e. multiple trauma), whereas 19% had facial injuries, and 9% had extremity fractures.

The majority of patients were discharged from the trauma hospital to local hospitals (46%) or rehabilitation units (41%). Of all patients, 73% received inpatient rehabilitation in the first year of injury, with mean length of stay 59 days (SD 37 days) among those receiving it. Demographics and injury-related characteristics are shown in Table I.

Table I. Demographics at time of injury and injury characteristics

| Variable | | Total, n |
|---|-------------|----------|
| Age at injury, mean (SD) | 30.3 (10.8) | 97 |
| Sex, n (%) | | 97 |
| Male | 76 (78.4) | |
| Female | 21 (21.6) | |
| Relationship status, n (%) | | 97 |
| Partnered | 28 (28.9) | |
| Single | 69 (71.1) | |
| Education level, years, n (%) | | 96 |
| ≤ 12 | 54 (56.3) | |
| > 12 | 42 (43.8) | |
| Employment status | | 97 |
| Yes | 80 (82.5) | |
| No | 17 (17.5) | |
| Occupational status, n (%) | | 97 |
| Blue-collar | 46 (47.4) | |
| White-collar | 51 (52.6) | |
| Disability pension | 4 (4.0) | |
| Injury cause, n (%) | | 97 |
| Traffic accident | 58 (59.8) | |
| Other | 39 (40.2) | |
| Glasgow Coma Scale score, mean (SD) | 7.2 (3.2) | 97 |
| Moderate (9–12) | 32 (33.0) | |
| Severe (3–8) | 65 (67.0) | |
| Post-traumatic amnesia, days, median (IQR) | 18.0 (2–38) | 88 |
| CT Head Marshall Score, n (%) | | 97 |
| Mean (SD) | 2.6 (1.1) | |
| Score 1–2 | 46 (47.4) | |
| Score 3+ | 51 (52.6) | |
| Body trauma location, n (%) | | 97 |
| Isolated TBI | 30 (30.9) | |
| TBI with additional extracranial injuries | 67 (69.1) | |
| Injury Severity Score, mean (SD) | 30.0 (13.6) | 97 |
| Total acute length of stay, days, mean (SD) | 29.0 (25.0) | 97 |
| In-patient rehab. length of stay, days, mean (SD) | 59.0 (37.0) | 71 |

IQR: interquartile range; SD: standard deviation; TBI: traumatic brain injury.

The frequency of use of PT, OT and ST services across the follow-up time is shown in Table II. PT use decreased from 57% at 1-year to 13% at 10-year follow-up. The use of OT services decreased from 19% at 1-year to 1% at 10-year follow-up, whereas the use of ST services decreased from 13% at 1-year to 3% 10-year follow-up. Overall, the use of services in 74 patients with data at both 1- and 10-year follow-up showed similar results, with statistically significant downward movement of service usage across the 4 follow-ups.

Of the total sample, 42% of patients did not receive any therapy at 1-year follow-up. Of those who received traditional rehabilitation services, 61% received one service, 25% 2 services and 14% all 3 services. At 10-year follow-up, 13% received one service, and only 1% received all 3 services.

Table II. Percentages of physical therapy (PT), occupational therapy (OT) and speech therapy (ST) service use across the follow-ups

| Year | PT, % | OT, % | ST, % | Total, n |
|------|-------|-------|-------|----------|
| 1 | 57 | 19 | 13 | 97 |
| 2 | 32 | 12 | 11 | 92 |
| 5 | 25 | 8 | 6 | 89 |
| 10 | 13 | 1 | 3 | 74 |

Table III. Frequency of physical therapy (PT), occupational therapy (OT) and speech therapy (ST) utilization according to the Glasgow Outcome Scale Extended (GOSE) outcome

| Year | GOSE | PT, % | χ^2 | OT, % | χ^2 | ST, % | χ^2 |
|------|--------------|-------|-----------|-------|-----------|-------|-----------|
| 1 | Unfavourable | 87 | $p=0.001$ | 48 | $p<0.001$ | 39 | $p<0.001$ |
| | Favourable | 47 | | 9 | | 19 | |
| 2 | Unfavourable | 75 | $p<0.001$ | 50 | $p<0.001$ | 43 | $p<0.001$ |
| | Favourable | 21 | | 1 | | 3 | |
| 5 | Unfavourable | 53 | $p=0.003$ | 13 | $p=0.272$ | 13 | $p=0.070$ |
| | Favourable | 18 | | 5 | | 3 | |
| 10 | Unfavourable | 18 | $p=0.292$ | 3 | $p=0.279$ | 3 | $p=0.524$ |
| | Favourable | 10 | | 0 | | 3 | |

GOSE was dichotomized into unfavourable (GOSE 3–5) and favourable (GOSE 6–8) outcome.

At 1-year follow-up, TBI patients with multiple injuries used PT services more often than those with isolated TBI (67% vs 30%, $p=0.002$). No statistically significant differences were found for the other services at 1-year follow-up or for any of the services (PT, OT, ST) at the subsequent follow-ups. At the 1- and 2-year follow-ups after the injury, patients with unfavourable outcome (GOSE 3–5) frequently used PT (87% and 75%), OT (48% and 50%) and ST (39% and 43%) services (see Table III). At the 5-year follow-up, PT services were still frequently used in the unfavourable outcome group (53%). No statistically significant differences were found for the other services at 5- and 10-year follow-ups. At the 1-year follow-up, individuals with lower FIM-Motor scores (i.e. functional mobility impairments and dependence in ADL) frequently used PT (92%) and OT (75%) services, whereas one-third used ST services (see Table IV). The majority of those with lower FIM-Cognitive scores (i.e. cognitive impairments and dependence in ADL) used PT services (74%), but OT and ST services were also frequently used at 1 year after injury (41% and 42%, respectively). At 5-year follow-up, those with lower FIM-Motor scores still frequently used PT services (83%), with one-third using OT and ST services. Of those with lower FIM-Cognitive scores, PT services were used by almost half of the individuals, whereas no significant differences were found for use of OT and ST services.

Table IV. Frequency of physical therapy (PT), occupational therapy (OT) and speech therapy (ST) utilization according to the Functional Independence Measure (FIM) Motor and Cognitive domain scores

| Year | FIM | Value | PT, % | χ^2 | OP, % | χ^2 | ST, % | χ^2 | |
|------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1 | Motor | ≤ 78 | 92 | $p=0.009$ | 75 | $p<0.001$ | 33 | $p=0.004$ | |
| | | ≥ 79 | 52 | | 10 | | 4 | | |
| | Cognitive | ≤ 30 | 74 | $p=0.028$ | 41 | $p=0.001$ | 42 | $p=0.002$ | |
| | | ≥ 31 | 49 | | 10 | | 9 | | |
| | 5 | Motor | ≤ 78 | 83 | $p<0.001$ | 33 | $p=0.023$ | 33 | $p=0.004$ |
| | | | ≥ 79 | 19 | | 6 | | 4 | |
| 5 | Cognitive | ≤ 30 | 44 | $p=0.041$ | 12 | $p=0.515$ | 12 | $p=0.226$ | |
| | | ≥ 31 | 19 | | 7 | | 4 | | |

The FIM-Motor and the FIM-Cognitive variables were dichotomized at the cut-off for dependence/independence in activities of daily living (ADL).

Unconditional models and unconditional growth models

Physical therapy use. The unconditional PT service use model yielded a statistically significant estimated participant variance of 0.06 (Wald $Z=3.82$, $p<0.001$), as well as a statistically significant estimated residual variance of 0.16 (Wald $Z=11.32$, $p<0.001$). The intraclass correlation coefficient (ICC) was calculated to be 0.27, indicating that approximately 27% of the total variance of PT use probabilities was associated with the participant grouping and violation of the assumption of independence of PT use. This suggests that there was sufficiently large clustering of PT use probability variance within participants to proceed with HLM. The unconditional growth model was then run separately with the successive additions of time, quadratic time, and cubic time in order to determine the shape of the best-fitting architecture of PT use probabilities over time (Table V), suggesting that a cubic (*S*-shaped) trajectory best fit PT use probability trajectories.

Occupational therapy use. The unconditional OT use model yielded a statistically significant estimated participant variance of 0.02 (Wald $Z=3.47$, $p<0.001$), as well as a statistically significant estimated residual variance of 0.07 (Wald $Z=11.20$, $p<0.001$). The ICC was 0.22, suggesting that the assumption of independence in OT use was violated. The unconditional growth model was run separately, as before (Table V), finding that a linear trajectory best fit OT use probabilities over time.

Speech therapy use. The unconditional speech therapy use model yielded a statistically significant estimated participant variance of 0.03 (Wald $Z=4.54$, $p<0.001$), as well as a statistically significant estimated residual variance of 0.05 (Wald $Z=11.33$,

Table V. Unconditional growth model fit for therapy service use probability trajectories over time

| Model | -2 Log likelihood |
|---------------------------------|-------------------|
| Physical therapy use | |
| Linear | 397.75 |
| Quadratic | 389.59 |
| Cubic | 379.98 |
| Occupational therapy use | |
| Linear | 144.12 |
| Quadratic | 143.33 |
| Cubic | 143.11 |
| Speech therapy use | |
| Linear | 68.24 |
| Quadratic | 67.39 |
| Cubic | 66.49 |

Critical χ^2 value for significant difference at $\alpha=0.05$ is ≥ 3.841 reduction from the previous model.

Table VI. Demographic and injury predictors of physical therapy (PT) use probability trajectories across 1, 2, 5 and 10 years

| Predictor | b-weight | SE | p-value | 95% confidence interval | |
|--|-----------|-------|---------|-------------------------|-------------|
| | | | | Lower bound | Upper bound |
| Intercept | 0.505*** | 0.084 | < 0.001 | 0.339 | 0.672 |
| Time | -0.357*** | 0.081 | < 0.001 | -0.515 | -0.198 |
| Time*Time | 0.093** | 0.027 | 0.001 | 0.039 | 0.147 |
| Time*Time*Time | -0.007** | 0.002 | 0.002 | -0.011 | -0.002 |
| Sex (1 = female, 0 = male) | 0.196** | 0.063 | 0.003 | 0.069 | 0.322 |
| Age | 0.002 | 0.003 | 0.582 | -0.004 | 0.008 |
| Relationship status (1 = partnered, 0 = single) | -0.023 | 0.069 | 0.734 | -0.160 | 0.113 |
| Education | -0.009 | 0.035 | 0.809 | -0.078 | 0.061 |
| Employment (1 = employed, 0 = unemployed) | 0.084 | 0.070 | 0.234 | -0.055 | 0.222 |
| Occupational status (1 = white-collar, 0 = blue-collar) | -0.056 | 0.061 | 0.362 | -0.176 | 0.065 |
| Glasgow Coma Scale score | 0.001 | 0.010 | 0.906 | -0.018 | 0.020 |
| Cause of injury (1 = motor vehicle, 0 = not motor vehicle) | -0.092 | 0.060 | 0.127 | -0.212 | 0.027 |
| Post-traumatic amnesia | 0.005*** | 0.001 | < 0.001 | 0.003 | 0.007 |
| CT Severity Score | -0.063* | 0.026 | 0.017 | -0.115 | -0.011 |
| Injury Severity Score | 0.003 | 0.002 | 0.185 | -0.001 | 0.007 |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. SE: standard error.

$p < 0.001$). The ICC was 0.38, suggesting violation of the assumption of independence. Again, an unconditional growth model was run separately (Table V), suggesting that a linear trajectory best fit ST use probabilities over time.

Full models

Physical therapy use. A full HLM examined whether trajectories of PT use probabilities over time could be predicted by demographic and injury characteristics at baseline. All statistically significant and non-significant fixed effects from the full HLM and their b-weights, p-values, and 95% confidence intervals are shown in Table VI. PT use probabilities continued to show a significant cubic (S-shaped) curve, suggesting a steep initial decrease over time, a plateau, and then a final decrease. Sex, PTA, and CT severity score yielded statistically significant effects on participants' PT use probability trajectories. Women had a higher overall probability trajectory of PT use across the 4 time-points than men (Fig. 1). Individuals with a longer length of PTA had a higher probability trajectory of PT use than those with shorter lengths of PTA (Fig. 2). After careful consideration, the CT severity score effect was interpreted as likely due to low-to-moderate multicollinearity among the predictors, and therefore was a statistical suppressor effect without substantive interpretation.

Occupational therapy use. As before, a second full HLM examined whether linear trajectories of OT use probabilities over time could be predicted by demographic and injury characteristics at baseline (Table VII). OT use probabilities declined over time in a linear trajectory across the full sample. Age, relationship status, employment at injury, and PTA yielded statistically significant effects on participants' OT use probability trajectories. People who had been employed at injury

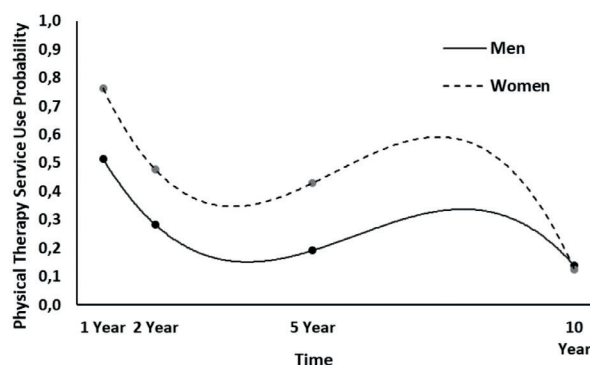


Fig. 1. Main effect of sex on physical therapy (PT) service use probability trajectories.

had a higher probability trajectory of OT use than those who had been unemployed (Fig. 3). Individuals with a longer length of PTA had a higher probability trajectory of OT than those with a shorter length of PTA (Fig. 4). Finally, when effects of both age and relationship status were plotted, no discernible visual trends emerged,

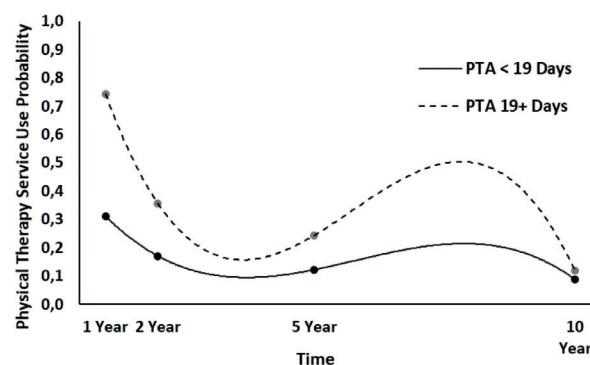


Fig. 2. Main effect of post-traumatic amnesia (PTA) on physical therapy (PT) service use probability trajectories.

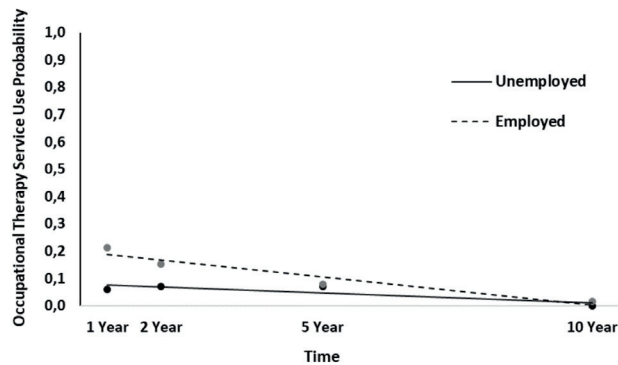


Fig. 3. Main effect of employment at injury on occupational therapy (OT) service use probability trajectories.

suggesting that these effects also were probably due to low-to-moderate multicollinearity among predictors, and therefore devoid of substantive interpretation.

Speech therapy use. A third full HLM examined whether linear trajectories of speech therapy use probabilities over time could be predicted by demographic and injury characteristics at baseline (Table VIII). Speech therapy use probabilities decreased in a linear

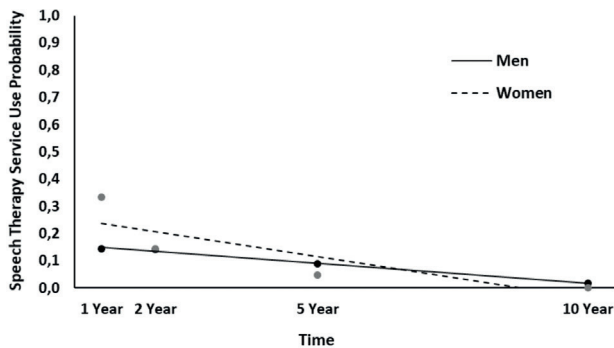


Fig. 5. Main effect of sex on speech therapy (ST) service use probability trajectories.

fashion over time across the full sample. Sex and PTA yielded statistically significant effects. Women had a higher overall speech therapy use probability trajectory; although a visual inspection suggested that this effect was primarily due to much higher speech therapy probability use among women at 1-year follow-up (Fig. 5). In addition, individuals with a longer length of PTA had a higher probability trajectory of speech therapy use over time (Fig. 6).

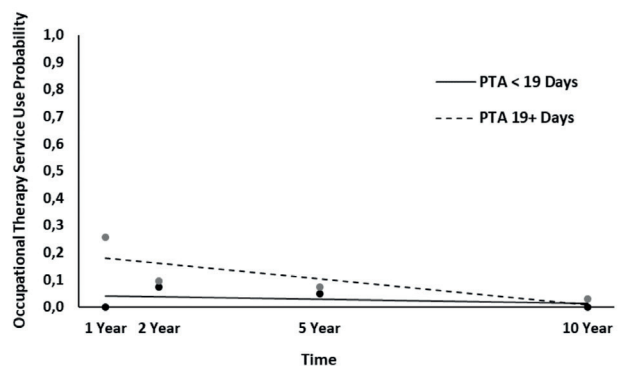


Fig. 4. Main effect and time interaction of post-traumatic amnesia (PTA) on occupational therapy (OT) service use probability trajectories.

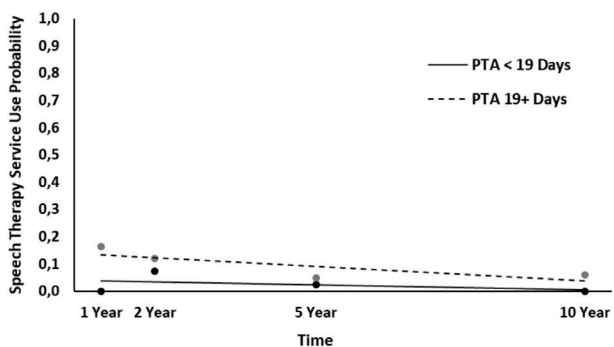


Fig. 6. Main effect of post-traumatic amnesia (PTA) on speech therapy (ST) service use probability trajectories.

Table VII. Demographic and injury predictors of occupational therapy (OT) use probability trajectories across 1, 2, 5 and 10 years

| Predictor | b-weight | SE | p-value | 95% confidence interval | |
|--|----------|-------|---------|-------------------------|-------------|
| | | | | Lower bound | Upper bound |
| Intercept | 0.035 | 0.052 | 0.496 | -0.068 | 0.139 |
| Time | -0.011** | 0.004 | 0.004 | -0.019 | -0.004 |
| Sex (1 = female, 0 = male) | 0.066 | 0.041 | 0.112 | -0.016 | 0.147 |
| Age | 0.004* | 0.002 | 0.035 | 0.000 | 0.008 |
| Relationship status (1 = partnered, 0 = single) | -0.093* | 0.044 | 0.038 | -0.181 | -0.005 |
| Education | 0.010 | 0.023 | 0.666 | -0.035 | 0.055 |
| Employment (1 = employed, 0 = unemployed) | 0.090* | 0.045 | 0.049 | 0.000 | 0.179 |
| Occupational status (1 = white-collar, 0 = blue-collar) | -0.002 | 0.039 | 0.959 | -0.080 | 0.076 |
| Glasgow Coma Scale score | -0.006 | 0.006 | 0.319 | -0.019 | 0.006 |
| Cause of injury (1 = motor vehicle, 0 = not motor vehicle) | 0.023 | 0.039 | 0.550 | -0.054 | 0.100 |
| Post-traumatic amnesia | 0.002** | 0.001 | 0.004 | 0.001 | 0.003 |
| CT Severity Score | -0.003 | 0.017 | 0.840 | -0.037 | 0.030 |
| Injury Severity Score | 0.000 | 0.001 | 0.750 | -0.003 | 0.002 |

*p < 0.05; **p < 0.01; ***p < 0.001. SE: standard error.

Table VIII. Demographic and injury predictors of speech therapy (ST) use probability trajectories across 1, 2, 5 and 10 years

| Predictor | b-weight | SE | p-value | 95% confidence interval | |
|--|----------|-------|---------|-------------------------|-------------|
| | | | | Lower bound | Upper bound |
| Intercept | 0.099 | 0.054 | 0.071 | -0.009 | 0.206 |
| Time | -0.008* | 0.003 | 0.020 | -0.014 | -0.001 |
| Sex (1 = female, 0 = male) | 0.102* | 0.044 | 0.023 | 0.015 | 0.188 |
| Age | -0.001 | 0.002 | 0.640 | -0.005 | 0.003 |
| Relationship status (1 = partnered, 0 = single) | -0.070 | 0.047 | 0.143 | -0.164 | 0.024 |
| Education | 0.019 | 0.024 | 0.437 | -0.029 | 0.067 |
| Employment (1 = employed, 0 = unemployed) | 0.038 | 0.048 | 0.433 | -0.057 | 0.132 |
| Occupational status (1 = white-collar, 0 = blue-collar) | -0.040 | 0.042 | 0.341 | -0.122 | 0.043 |
| Glasgow Coma Scale score | -0.004 | 0.007 | 0.578 | -0.017 | 0.010 |
| Cause of injury (1 = motor vehicle, 0 = not motor vehicle) | -0.045 | 0.041 | 0.284 | -0.127 | 0.038 |
| Post-traumatic amnesia | 0.002** | 0.001 | 0.007 | 0.001 | 0.003 |
| CT Severity Score | -0.005 | 0.018 | 0.765 | -0.041 | 0.030 |
| Injury Severity Score | 0.000 | 0.001 | 0.750 | -0.002 | 0.003 |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. SE: standard error.

Final models with time interactions

Physical therapy use. The first final HLM examined whether PT use probability trajectories could be predicted by the previously significant and meaningful predictors (sex and PTA), as well as their interactions with cubic time. Neither of the interaction terms was statistically significant (all $ps \geq 0.592$), suggesting that PT use probabilities did not change differentially over time as a function of either of these predictors.

Occupational therapy use. A second HLM examined whether OT use probability trajectories could be predicted by employment and PTA and their interactions with time. The PTA*time interaction term was the only statistically significant interaction term ($p = 0.001$), suggesting that OT use probabilities decreased with a greater downward slope for individuals with a longer PTA than for those with a shorter length of PTA (Fig. 4).

Speech therapy use. A final HLM examined whether speech therapy use probability trajectories could be predicted by sex and PTA and their interactions with time. The PTA*time interaction approached significance ($p = 0.051$).

DISCUSSION

This study describes the long-term trajectories of PT, OT and ST use at 1, 2, 5 and 10 years following moderate-to-severe TBI. The utilization of services decreased substantially over time, with PT being the main service received at the 10-year follow-up (PT 16%, OT 1%, ST 3%) in line with a study by Hodgkinson et al. (13). Furthermore, we found that the use of therapy was related to injury severity, female sex, and pre-injury employment status.

In our study, we anticipated a substantial decrease in service use from 1- to 10-year post-injury, based on the experience that many of the impairments would

recover after some time, and correspondingly a need for services in the long-term perspective would decrease. As expected, modelling the probability of OT and ST use revealed a substantial decrease in the first 10 years post-injury, with few patients receiving these services at the 5- and 10-year follow-ups. In contrast, the modelling of PT use probabilities showed a significant cubic curve, suggesting a steep initial decrease up to 2 years after injury, plateauing, and then a final decrease. A substantial number of patients received PT at least up to 5 years post-injury in line with other studies of service provision in the post-acute phase of TBI, showing that PT is the most frequently used rehabilitation service (8). TBI with accompanying extracranial injuries was frequently present in this study, in line with other studies conducted in trauma hospitals (30). Hence, PT services may have been used for treatment of accompanying orthopaedic injuries at least during the first year after the injury. Individuals with lower FIM-Motor and FIM-Cognitive scores (i.e. dependence in ADL) showed significantly higher use of PT, OT and ST services at 1-year follow-up. Similarly, there was a significantly higher use of all services at 5-year follow-up among those with lower FIM-Motor scores, whereas this applied only to PT services for those with lower FIM-Cognitive scores. A longitudinal study from Australia found that approximately 80% of individuals had good mobility across 10 years after mild-to-severe TBI, whereas approximately 8% reported walking independently with aids and 5% reported low mobility at year 10 (31). Another study found that one-third of people with TBIs with accompanying injuries experience impairments and chronic pain in need of treatment from a long-term perspective (32). A registry-based study from Denmark reported that patients with TBI aged 20–64 years had an increased use of healthcare services across 9 years after the injury compared with controls (21). The use of PT was most frequent during the periods of 1–4 years post-injury

and 8–9 years post-injury. The authors highlighted that a possible explanation for this high frequency of PT may be related to use of both individual treatments and group-based training. In the previously mentioned French study, services addressing TBI impairments (PT, ST) were more frequently provided than services addressing activities and participation (such as OT) 4 years after severe TBI (8). In this study, PT services were used in most patients with severe disability/lower level of moderate disability (GOSE<6) in the first 2 years following injury. OT and ST services were also frequently used in this follow-up period, but the use of services decreased considerably in the long-term perspective.

Predictors of physical therapy, occupational therapy and speech therapy services

More than half of the study population had severe injuries, as assessed by PTA and CT severity scores, and two-thirds presented chronic disability, as assessed by the GOSE at 10-year follow-up (33). Service use depends on needs and availability. The hypothesis that the use of services would be associated with more severe TBI was supported for PT, OT and ST services, in line with previous studies (8, 13). Patients with moderate-to-severe disability may be in need of continuous functional and maintenance training (20). Taking into account the frequency of patients with chronic disability in this population reported in a previous publication (33), and that the use of services in the patient group with unfavourable outcome (GOSE<6) decreased substantially at 5- and 10-year follow-ups, the study results may indicate an under-provision of services from a long-term perspective. This may highlight the decision-making challenge that clinicians often face when determining long-term interventions for individuals with brain injuries (i.e. when to refer and to whom). Regular healthcare follow-ups can help to identify individuals' functional problems over time and to address their specific need for treatment. As expected, female sex was associated with a higher use of PT and partly ST (the first 2 years). This could be related to a general trend of higher healthcare use in women compared with men (due to women's tendency to report higher rates of symptoms) (15, 34). In addition, this may reflect statements that women are in need of more rehabilitation services due to a worse long-term functional outcome, as reported in our previous study using the same sample of patients, and several other studies, including a study that compared women without TBI with those with TBI (33, 35, 36). However, a skewed sample related to sex distribution in this study calls for caution regarding generalization of the results.

Time since injury was associated with use of OT and ST in this sample. Furthermore, the use of OT was associated with employment at the time of injury. This is not a surprising result, as one of the roles of OT is to support productivity and return to work (37). The results may also reflect that the population in this study was of working age (16–55 years), and that rehabilitation efforts in order to improve the productive lifestyle of people with TBI are of importance (25, 38).

Strengths and limitations

The greatest strength of this study is that it is the first Nordic prospective longitudinal study to describe the probability of use of TBI rehabilitation services over a period of 10 years post-injury in a geographical region that covers more than half of Norway's population. However, several limitations should be considered when interpreting the results. First, a methodological limitation is that the main source of information for assessing the use of therapy was self-reported. This may have over- or underestimated the true use of therapy, because some patients with severe TBI have memory problems; however, the relatives of patients who were severely injured participated at the follow-up and confirmed the use of services. In addition, a study by Hart et al. suggested that people with severe TBI can self-report their utilization of outpatient therapies with reasonable accuracy (39). Secondly, we assessed service use within the last 3 months before each follow-up time-point; as such, the results do not necessarily represent service use per year. In addition, this study assessed only 3 traditional rehabilitation services. As the study was conducted in the trauma hospital population, two-thirds of patients had TBI with multiple injuries. However, it is worth mentioning that TBI was the principal diagnosis in this patient population. Information regarding what kind of impairments and functional limitations the services were targeting, and the response to treatments, were, unfortunately, not recorded. Such information may have provided further insights into the effectiveness of the service provision. Thirdly, we do not have information on service availability and whether the participants declined any services. Consequently, it was not possible to directly investigate whether under- or over-treatment took place. Of the mentioned services, only PT is required by law (Health and Care Services Act) as part of the municipal service delivery. Given the large geographical area of Norway, service availability can vary significantly and, in addition, the municipal decision-making process involved in service provision can differ over a decade. Thus, the provision of services might have influenced the present results. Fourthly, the study sample represents individuals in the age range

16–55 years, which means that the use of therapy in older individuals is unknown. Fifthly, the sample is relatively small and, as with any longitudinal study, there were missing data (which were estimated using full-information maximum likelihood). Finally, a comparison group of individuals with another condition (e.g. orthopaedic injuries, stroke) would have provided useful information about the need for therapies in the TBI population vs other patient populations.

Conclusion

The trajectories of rehabilitation service utilization observed in this study indicate that participants received PT, OT and ST in a variable manner from 1- to 10-year follow-ups. A decline in service use was observed across the follow-up time although individuals with moderate-to-severe TBI had documented ongoing functional impairments. Hence, our results may suggest an insufficient long-term provision of traditional TBI rehabilitation services.

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