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Use of the Disability Rating Scale recovery curve as a predictor of psychosocial outcome following closed-head injury

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Abstract

Rapid rate of recovery has been associated with better outcome following closed-head injuries, but few studies have compellingly demonstrated this. This study used growth curve analyses of Disability Rating Scale (DRS) scores at acute hospitalization discharge, 1, 3, and 6 months post injury in a sample of 55 patients with a closed-head injury. Six month post-injury outcome measures were taken from significant other (SO) responses on the NYU Head Injury Family Interview (NYU-HIFI) including severity and burden ratings of affective/neurobehavioral disturbance, cognitive deficits, and physical/dependency status. Rate of recovery (linear and curvilinear recovery curve components) was significantly related to the level of affective/neurobehavioral severity, and the severity and burden of SO-perceived cognitive deficits. Only the intercept of the DRS recovery curve was associated with the SO-perceived severity and burden of physical/dependency status. Growth curve modeling is a meaningful and powerful tool in predicting head injury outcome. (*JINS*, 2001, *7*, 457–467.)

Keywords: Closed-head injury, Growth curves, Outcome measures, Outcome prediction, Disability Rating Scale

INTRODUCTION

Rate of recovery from injury, based on clinical experience, has long been assumed to be related to outcome; that is, the more rapid the recovery from trauma the better the outcome. In the head injury literature, the validity of this had not been rigorously demonstrated until Fleming and Maas (1994). These researchers used the percent change in the Disability Rating Scale (DRS) score from rehabilitation admission to discharge divided by the number of weeks in the rehabilitation program as their measure of rate of recovery. Percent change in DRS score, along with the rehabilitation admission DRS score, accounted for 62% of the variance in the rehabilitation discharge DRS score. This finding is not entirely surprising because of the high correlation shown in numerous studies between two DRS scores separated by short spans of time. However, the addition of a rate of recovery term in the outcome equation greatly improved prediction accuracy above other acute injury variables (i.e., duration of posttraumatic amnesia, or preinjury demographics, etc.). These findings suggest that knowing the intercept (admission DRS) and the slope (percent change over time in rehabilitation) could improve prediction of outcome (discharge DRS). Although an important step forward, this technique fails to capture nonlinear (or curvilinear) changes in a patient's DRS level which may be important and substantially increase prediction of outcome. What is needed is a technique that will capture all this information.

Growth curve modeling (Bryk & Raudenbush, 1987a, 1987b; Francis et al., 1991, 1996) takes all three characteristics into account. This modeling technique (also referred to as random coefficient modeling or "mixed modeling" for statistical software such as SAS) allows for the estimation of recovery curves for individual patients for a specific time point (intercept), as well as the rate of recovery (slope), and nonlinear changes in the rate of recovery (curvilinearity) that are occurring at that time point. It should be noted that recovery in this context is not meant to imply a sequelae-

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free outcome, but instead simply the process of improvement over time following a traumatic brain injury. Bryk and Raudenbush (1987a) describe a two-stage model to conceptualize growth curve modeling. First, it is assumed that a systematic trajectory or curve plus random error varies across individuals. This is the within-subjects model and the parameters of this model, which can be random or fixed, represent the level and change in a measure over time (e.g., a measure of reading skill acquisition). Then at the second stage the individual parameters can be modeled as a function of some observable variable or variables (e.g., clinical group or type of reading instruction). This is the between-group model. Parameters of the between-group model are usually fixed effects and the errors are the random effects (variation in the individual growth parameters not associated with the between-subjects variables). Although this is a very flexible modeling procedure, some assumptions must be met. Variables used in the within-subject model must be distributed as multivariate normal and these variables must be measuring the same construct on a common metric. The timing and number of individual data points in the within-subjects model need not be uniform. In order to model recovery curves (as in this study), a minimum of three time points are required. Although this analytic technique usually employs predictors (e.g., high-risk groups, schools, reading ability levels, etc.) to determine their effect on the shape of the growth curve, the process could be interpreted in reverse using analyses that are arithmetically identical. In essence, a recovery curve based on an index of impairment and/or disability could be interpreted as predicting specific outcome variables. To fully characterize the recovery curve, the same instrument would need to be used from the acute hospitalization until the final outcome time point.

The DRS has become an accepted measure of outcome in head injury (Rappaport et al., 1977, 1982). DRS scores have been shown to be significantly correlated with the integrity of cortical functioning following brain trauma as determined by evoked potential studies in comatose or near-comatose patients (Rappaport, 1986; Rappaport et al., 1977, 1981, 1989a, 1990, 1991). The DRS has high interrater reliability (Rappaport et al., 1982), predictive validity (Eliason & Topp, 1984; Gouvier et al., 1987), and concurrent validity with other functional and cognitive assessment instruments (Gouvier et al., 1987; Hall et al., 1985, 1993; Malec & Thompson, 1994). The DRS has also been widely used in rehabilitation studies in which the admission DRS score was found to be highly predictive of discharge DRS scores (Fleming & Maas, 1994; Fryer & Haffey, 1987; Giancino et al., 1991; Rao & Kilgore, 1992; Rappaport et al., 1989a; Thatcher et al., 1991) and return to work 2 years post injury (Ponsford et al., 1995). The DRS has been shown to be an adequate instrument for characterizing patients from coma to community re-entry (Rappaport et al., 1982, 1989b), and is not sensitive to preinjury demographic variables (Hedrick et al., 1995). Rasch analysis (which transforms scales from an ordinal or interval scale to a ratio scale) has demonstrated that the level of difficulty represented by the DRS items is excellent ranging from low-level functioning items such as *Eye Opening* to higher-level cognitive functioning items such as *Employability* (Hall et al., 1993). The DRS has met with some criticisms including the relative insensitivity to change for patients having mild head injuries and those in the vegetative state or extremely vegetative range, and has large gaps in item difficulty (Hall et al., 1993). In spite of these criticisms, the DRS appears to be much more sensitive to changes in recovery than the Glasgow Outcome Scale (GOS), and it has been considered by some researchers to be the best instrument currently available for determining outcomes in head injury clinical trials (Clifton et al., 1992).

Of course, after determining the appropriate instrument to adequately characterize recovering patients, an appropriate outcome measure for prediction must be identified. Researchers have called attention to the particular problems facing the family members and significant others (SO) of the head-injured. Different types of patient deficits produce different levels of stress or "subjective burden" as reported by family members and SOs over the course of recovery. These deficits range from physical disabilities and cognitive impairments to behavioral and emotional dysfunction. Previous research has suggested that subjective burden related to physical disability tends to ease relatively quickly. However, the chronic stressors of emotional and behavioral dysfunction appear to produce the most enduring subjective burden in the families of the head-injured (Brooks & McKinlay, 1983; Brooks, 1984; Brooks et al., 1984, 1986, 1987; Kreutzer et al., 1992, 1994a, 1994b, 1994c; Leaf, 1993; Lezak, 1978, 1988; McKinlay et al., 1981; Oddy et al., 1978a, 1978b; Rosenbaum & Najenson, 1976). Although functional outcomes are important, particularly in clinical trials, the patient's outcome from the SO and family's perspective should seriously be considered as well.

To quantify meaningful sequelae following head injury adequately, the research would need an instrument which could be administered in a consistent manner to gather systematic data on a wide variety of symptomatology related to traumatic brain injury. The New York University Head Injury Family Interview (NYU-HIFI) is one such instrument. The NYU-HIFI is a set of structured interviews and checklists designed to obtain information about the SO's perceptions of the incidence, severity and burden of injury-related changes in the head-injured patient. This instrument has been shown to have adequate reliability and validity for use in a head-injured population (Cavallo et al., 1992; Kay et al., 1995; Schentzel, 1993). Subjective burden (as measured by the NYU-HIFI) reported by SOs was found to be significantly correlated with neuropsychological deficits, memory in particular (Schentzel, 1993). The measures of interest in this study are the SO's perception of the severity and burden of (1) affective/neurobehavioral disturbances, (2) cognitive deficits, and (3) physical/dependency symptoms at 6 months post injury. These measures were specifically chosen with two purposes in mind. The first was to employ outcome measures which have more relevance for a SO. Secondly, it would appear very difficult to find a relation between a measure of disability, such as the DRS, and a SO's perception of psychosocial outcome at 6 months post injury. Positive results given such constraints would provide convincing evidence of the usefulness of using DRS recovery curves to predict outcome.

Hypotheses

This research was designed to test the hypotheses that the DRS recovery curves would predict the severity and burden of a patient's affective/neurobehavioral disturbance (from the SO's perspective) at 6 months post injury. Since family members tend to adapt and/or adjust relatively quickly to cognitive and physical deficits, it was anticipated that the DRS recovery curve would not be related to the severity or burden of perceived cognitive deficits and physical/dependency status at 6 months post injury.

METHODS

Research Participants

Patients included in this study were selected from a series of consecutive admissions who presented at Ben Taub General Hospital, a Level-1 trauma center in Houston, Texas. Injury severity categories included complicated-mild, moderate, and severe closed-head injuries.

Exclusion criteria for this study include: preinjury psychiatric history of major psychiatric disorder (e.g., schizophrenia or an affective psychosis), report of significant previous brain injury (resulting in a loss of consciousness of more than a few minutes, or marked chronic sensorimotor defect), a history or the presence of other neurological disorders (i.e., epilepsy), or failure to obtain consent for participation. Patients who were in coma or a persistent vegetative state (PVS) on the DRS (scores 22–29) at 6 months post injury were excluded from this study. Often, head-injured patients are found to have a history of substance or polysubstance abuse. Those with a history of alcohol and/or drug abuse were not excluded from this study since to do so would have resulted in a sample that was not truly representative of the general head-injured population.

Inclusion criteria for the current study were patients with a complicated-mild, moderate, or severe closed-head injury between the ages of 15 and 55 who survived at least 6 months after their injury. In this study, a complicated-mild head injury was operationally defined as one in which a patient obtained a best Day 1 Glasgow Coma Scale (GCS) score, the highest GCS score within 24 hr following trauma, of 13 or more, and CT abnormalities. Patients with moderate head injuries had a best Day 1 GCS of 9 to 12 (with or without CT abnormalities) while those with severe head injuries had a best Day 1 GCS of 3 to 8 with or without CT abnormalities. Characteristics of the sample are presented in Table 1.

Table 1. Demographic characteristics of the consented group

Variable	SO report ($N = 55$)	No SO report ($N = 83$)
Age	32.0 (13.6)	31.38 (10.03)
Sex	Male = 46; Female = 9	Male = 67; Female = 16
Ethnicity		
White	22	34
Black	11	20
Hispanic	21	25
Other	1	4
Education (years)	10.38 (3.79)	10.98 (3.27)
Primary language		
English	40	59
Spanish/Other	15	24
Best Day 1 GCS	10.04 (3.34)	9.80 (3.54)
Injury severity		
Complicated-Mild	16	22
Moderate	15	16
Severe	24	45

At the time of this study, 138 head-injured patients had agreed to be followed to 6 months post injury to obtain information necessary to determine GOS (Jennett & Bond, 1975) and DRS scores. Seventy-eight of these patients also agreed to participate to the completion the NYU-HIFI and neuropsychological assessments. Of these 78 patients, 55 (70.5%) also had SOs who were willing to complete the NYU-HIFI, measures of handicap and substance abuse along with other inventories which addressed their own well-being. There were no significant differences between patients with and without SO reports for sex [$\chi^2(1, N = 138) = 0.19$, $p = .66$], ethnicity [$\chi^2(3, N = 138)$ $p = .63$], primary language [$\chi^2(1, N = 138) = 0.04$, $p = .83$], or severity grouping based on best Day 1 GCS [$\chi^2(2, N = 138) = 1.76$, $p = .41$]. There were no significant differences between the groups with respect to age [$t(134) = -0.3$, $p = .76$], education [$t(131) = 0.95$, $p = .34$], or best Day 1 GCS [$t(136) = -0.38$, $p = .70$]. Table 2 details the mechanisms and settings of injury in the studied sample.

Procedure

Consent for participation in this study was obtained initially from a SO (or other appropriate family member) as soon as possible upon the patient's arrival at the Neurosurgery Intensive Care Unit (NICU). Consent was also obtained from a SO (or family member) for their participation in the study in order to provide information regarding the impact of the injury on that person and/or the family. Patients participating in this study were evaluated on the DRS at discharge from acute hospitalization, 1, 3, and 6 months post injury, during which time sufficient information was gathered from direct observation, interview with the patient and SO (when possible), in addition to reports

Table 2. Mechanisms and settings of injuries in the studied sample

	N	%
Mechanisms		
Motor vehicle accident	34	61.8
Bicycle	2	3.6
Fall/Jump	5	9.0
Assault/Fight	13	23.6
Explosion	1	1.8
Settings		
Occupant of motor vehicle	27	49.0
Auto–pedestrian	8	14.5
Nonvehicular accident	17	30.9
Auto–bicycle accident	1	1.8
Unknown	2	3.6

from physicians, nursing staff, speech, occupational, and physical therapists, etc., and SO after the patient returned home. Information to complete a DRS was obtained from the patient and SO, by phone if necessary, on the appropriate follow-up date if the patient was unable to return for follow-up or if the patient lived more than 160 km outside the Houston area. Research technicians obtaining DRS information were extensively trained and the quality of the data collected was monitored in weekly review sessions by the second author (H.J.H.) to determine the adequacy and reliability of the responses on the DRS including those conducted in person or via telephone interview. If the research group did not agree that enough information had been obtained to accurately determine a DRS score, additional interviews and data were obtained until consensus was reached. Five neuropsychology technicians (individually trained by HJH) made the DRS ratings over the course of this study. These individuals were in contact with the patients when they arrived at the NICU, performed follow-up phone contacts with the patients and/or SO, and performed assessments at each follow-up time point. The patient's SO was interviewed at the 6 month post-injury assessment at which time they completed the NYU-HIFI (Cavallo et al., 1992; Kay et al., 1995; Schentzel, 1993).

Raw data were collected on test forms in a patient file which is secured in the Neurosurgery Research offices at Ben Taub General Hospital. Data were then entered directly from test forms into a computer database program. Data were identified by study participant number to protect the confidentiality of the patient's information.

Statistical Analyses

For each of the hypotheses, ratings to questions comprising the SO's perception of the severity and burden scales of the patient's affective/neurobehavioral disturbances, perceived cognitive deficits, and physical/dependency were summed separately to yield 6 criterion variables. Only those responses which were reported as having been a change from the patient's premorbid status were included in these sums. These scores ranged on a rating scale from 1 (*no problem*) to 7 (*severe problem*). The same rating scale was used for the severity and burden measures of all three scales.

A growth curve analysis was used to determine how well the recovery curve of the DRS taken at 4 time points (acute hospitalization discharge, 1, 3, and 6 months post injury) predicted the SO's perception of the severity and burden of the affective/neurobehavioral, cognitive, and physical/dependency scales at 6 months.

RESULTS

Visual inspection of bivariate plots of the DRS scores and outcome measures indicated sufficient homoscedasticity. There were no missing data points in the DRS recovery curves or the outcome measures. The residuals of each of the growth curve models including a criterion variable (outcome measure) were normally distributed.

Recovery Curve Analyses

In the growth curve models for these hypotheses, time was centered at 30 days post injury as a time point within the acute care phase for most severe head-injured patients in this study. This methodology is in line with recommendations of Bryk and Raudenbush (1987b) who suggested avoiding extreme time points in order to reduce or eliminate the degree of multicolinearity resulting from the high correlation between the linear and nonlinear terms. Reported intercepts, slopes and curvilinear components of the recovery curves will therefore refer to the level of the DRS, and the rate of change in DRS scores occurring at the point in time where the model was centered (30 days post injury).

Visual inspection of the DRS recovery curve data graph (Figure 1) indicated substantial curvilinearity in that scores declined over time and tended to level off as they approached 180 days post injury. To capture this in the initial random coefficient model (without predictors), both linear and curvilinear terms were entered as random effects. However, the restricted maximum likelihood estimation in this model failed to converge within 50 iterations. The curvilinear term was then entered into the model as a fixed effect (by eliminating the random term for this parameter in the between-subjects model), after which the model converged within 50 iterations. This model indicated that the intercept, as well as the linear and curvilinear terms, were significantly different from zero ($p = .0001$ for each term).

Inspection of the random effect terms revealed significant random variation in the intercept ($p = .0001$), and the slope ($p = .0001$). The covariance between the slope and intercept was significant ($p = .0001$), and the two terms were inversely related. This indicates that the higher the level of the DRS at 30 days post injury (intercept), the steeper the negative slope. For this model, which does not include criterion variables, the expected level of the DRS at 30 days post injury (i.e., the level of the DRS score with no

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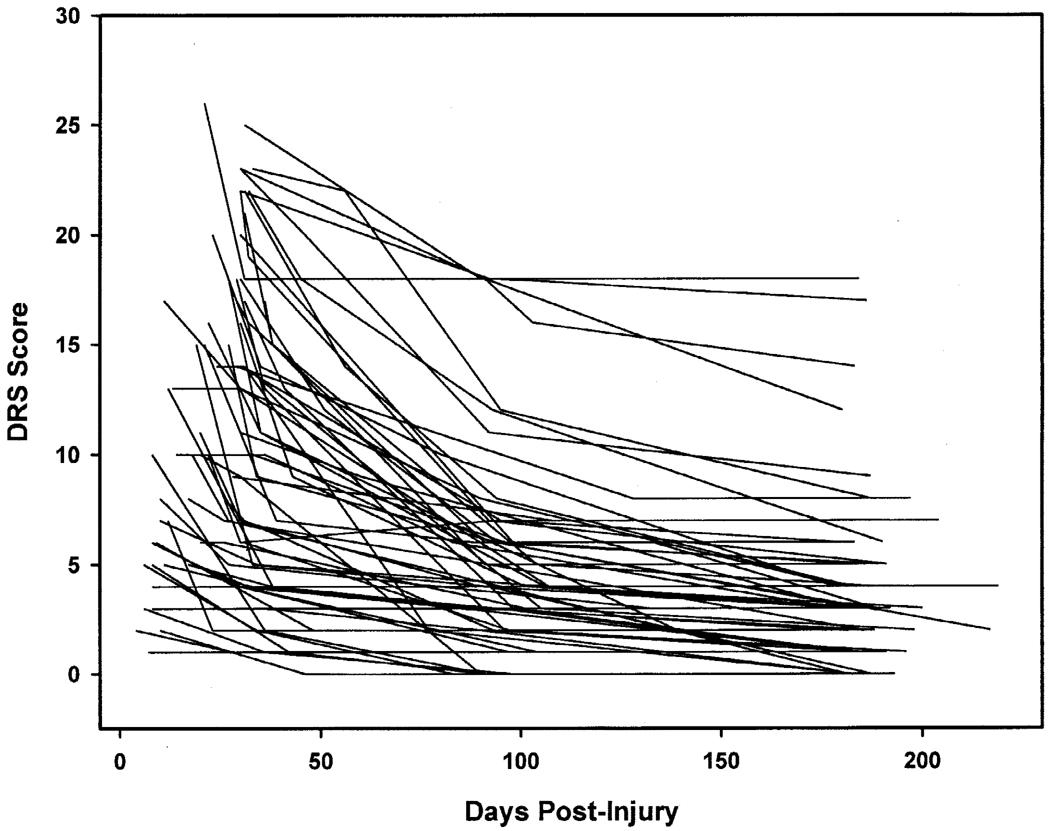

Fig. 1. *Individual DRS recovery curves*: This figure illustrates individual Disability Rating Scale recovery curves in aggregate for 55 participants.

other criterion variables entered into the model) is 10.79 which decreases by 0.11 points daily, but the rate of decrease slows by .0004 points per day *squared*. Essentially, the curve for the DRS scores decreases, but at a decreasing rate over time. Given that there was a significant level of random variation in the model, the criterion variables of interest (e.g., affective/neurobehavioral, etc.) were added to the model to investigate how they were related to the intercept, slope, and curvilinearity. The results of the following outcome models are summarized in Table 3.

Affective/Neurobehavioral Model

When examining how well the DRS recovery curve predicts the severity of affective/neurobehavioral symptoms at 6 months post injury, tests of fixed effects indicated that the level (intercept) of the DRS was not related to this outcome domain. However, the slope and the curvilinear terms were significantly associated with outcome. This suggests that it is not the level of the DRS at 30 days post injury that is important, but it is the linear and curvilinear rates of decline in the DRS scores which are associated with the SO's perception of the severity of affective/neurobehavioral symptoms at 6 months post injury. Specifically, less steep decline in the DRS scores was associated with more severe affective/neurobehavioral symptoms at 6 months, from the SO's perspective. Conversely, less severe affective/neurobehavioral symptoms were associated with a more rapid decline in the slope and curvilinear components of the DRS recovery curve (Figure 2). For the figures illustrating the DRS recovery curves in each model, *high* and *low* scores on the outcome measures are the highest and lowest possible scores for each factor score. The *medium* score is the median possible score for each factor score. The divisions were chosen primarily to illustrate characteristic curve shape based on the level of outcome.

With regard to affective/neurobehavioral burden, the intercept was not significantly related to outcome. Similarly, the slope as well as curvilinear components were not significantly correlated to outcome at 6 months. This suggests that although the rate of recovery (both linear and curvilinear components) of the DRS was significantly associated with the *severity* of affective/neurobehavioral symptoms, they were not associated with the *burden* that was reportedly experienced by the SO.

Cognitive Deficit Model

Consistent with expectation, the level (intercept) of the DRS recovery curve was not significantly associated with the degree of SO-perceived severity of cognitive deficits. How-

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Table 3. Summary of recovery curve results with the SO-reported NYU-HIFI outcome measures

Outcome measure	Parameter estimate	*T*-ratio	*p*
Affective/neurobehavioral			
Severity			
Intercept	.03	0.76	.46
Slope	.00069	2.02	.045*
Curvilinearity	−.000004	2.07	.04*
Burden			
Intercept	.0164	0.43	.67
Slope	.000389	1.18	.24
Curvilinearity	−.000002	1.3	.197
Cognitive deficits			
Severity			
Intercept	.0548	0.83	.4
Slope	.0015	2.61	.01*
Curvilinearity	−.000008	2.75	.007*
Burden			
Intercept	.015	0.23	.82
Slope	.00133	2.35	.02*
Curvilinearity	−.000007	2.38	.019*
Physical/dependency			
Severity			
Intercept	.281	4.68	.0001*
Slope	−.0006	−0.98	.33
Curvilinearity	0	0.03	.976
Burden			
Intercept	.277	4.11	.0001*
Slope	−.00044	−0.65	.52
Curvilinearity	0	−0.19	.85

*$p < .05$.

ever, contrary to expectation, the linear and curvilinear terms were significantly related to 6-month cognitive severity outcome as reported by the SO. Flatter slopes of the DRS curve at 30 days post injury are associated with greater severity of the SO's perception of cognitive deficits; DRS curves with rapidly declining scores were associated with less severe SO-perceived cognitive deficits (Figure 3).

Similarly, the intercept of the DRS recovery curve was not significantly associated with the SO's perception of cognitive burden at 6 months. However, both the linear and curvilinear components of the recovery curve were significantly associated with cognitive burden at 6 months, from the SO's perspective. Lower SO-perceived cognitive burden was associated with a steeply negative slope and a rapid approach to asymptote in the curvilinearity of the DRS recovery curve (Figure 4).

Physical/Dependency Model

Also in contrast to expectation, the level (intercept) of the DRS recovery curve was quite robustly associated with the SO's perception of the severity of physical/dependency symptoms at 6 months post injury. The slope and curvilinear terms were not significantly associated with outcome. The severity of physical/dependency symptoms was not associated with the rate of change (slope), or the rate of reaching asymptote (curvilinearity) in the DRS curve, but it was significantly associated with the *level* of the DRS at 30 days post injury (Figure 5).

Similar results were demonstrated for the level (intercept) of the SO's perception of the burden of physical/dependency status at 6 months. Again, the slope and curvilinear components were not significantly related to outcome. Higher levels of the DRS score (at 30 days) were associated with higher levels of the SO's perception of the severity and burden of physical/dependency symptoms at 6 months post injury.

In summary, linear and curvilinear components of the DRS recovery curves were significantly related to the SO's perception of the *severity* of affective/neurobehavioral disturbance, and the *severity* and *burden* of SO-perceived cognitive deficits. The shape of the DRS recovery curve was not predictive of SO-reported burden due to affective/neurobehavioral disturbance. Only the intercept of the DRS recovery curve was significantly associated with the *severity* and *burden* of physical/dependency which suggests that it is the level of disability at any point in time that accounts

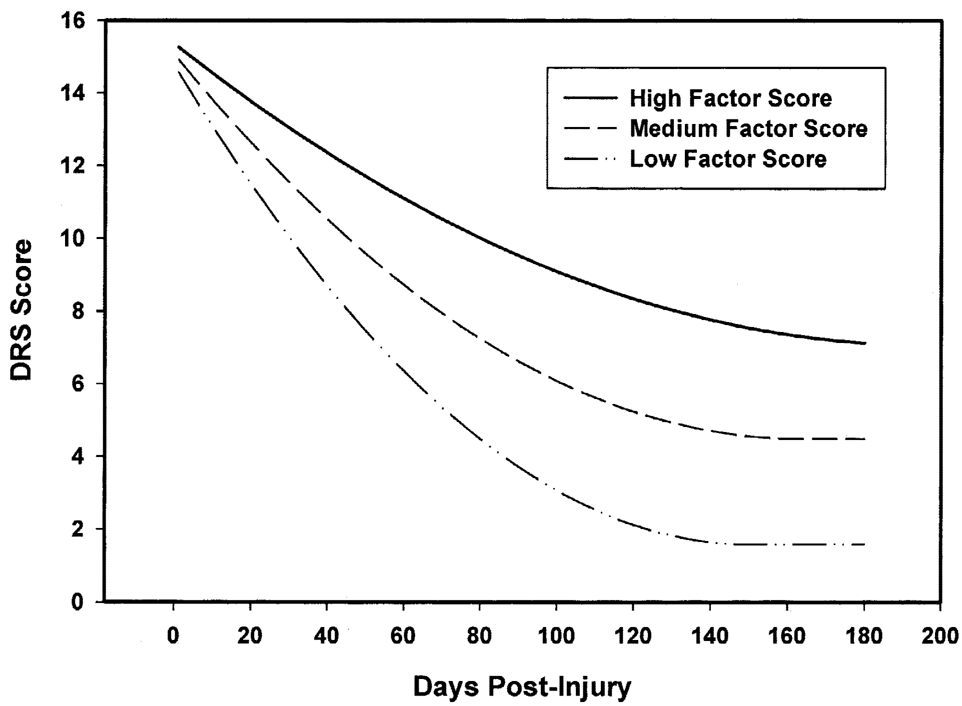

Fig. 2. *Recovery curves for high, medium, and low values of affective/neurobehavioral severity*: This figure depicts the DRS recovery curves based on the growth curve parameter estimates listed in Table 3 for Affective/Neurobehavioral Severity. Slower rate of recovery is associated with greater severity of SO-reported affective/neurobehavioral symptoms at 6 months (see text).

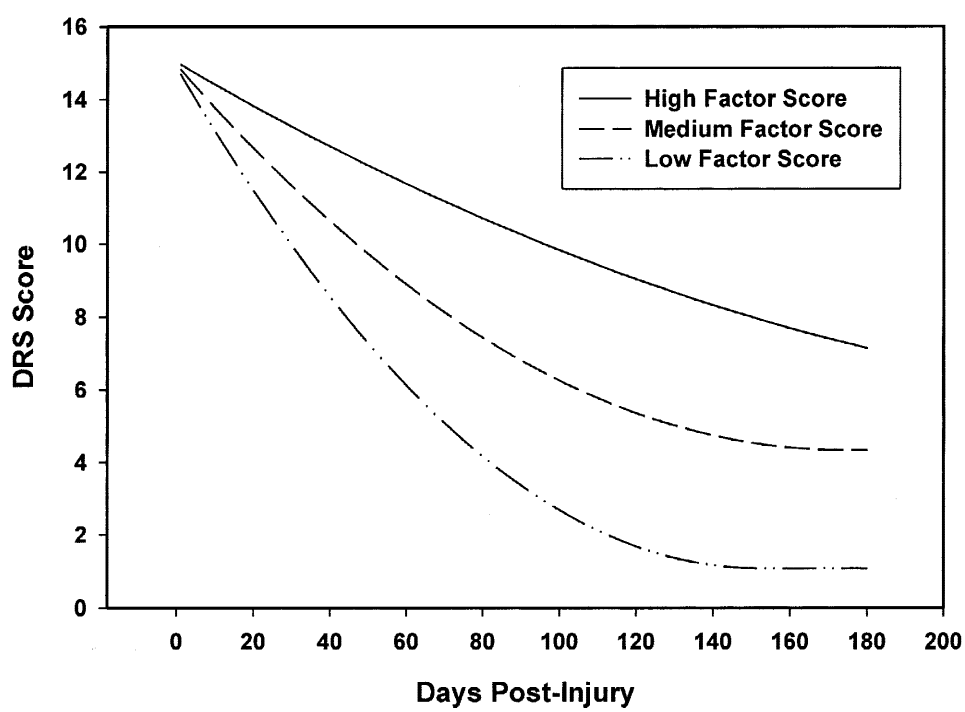

Fig. 3. *Recovery curves for high, medium, and low values of cognitive severity*: This figure presents the DRS recovery curves based on the growth curve parameter estimates listed in Table 3 for Cognitive Severity. Quicker rate of recovery is associated with less severe SO-reported cognitive deficits at 6 months.

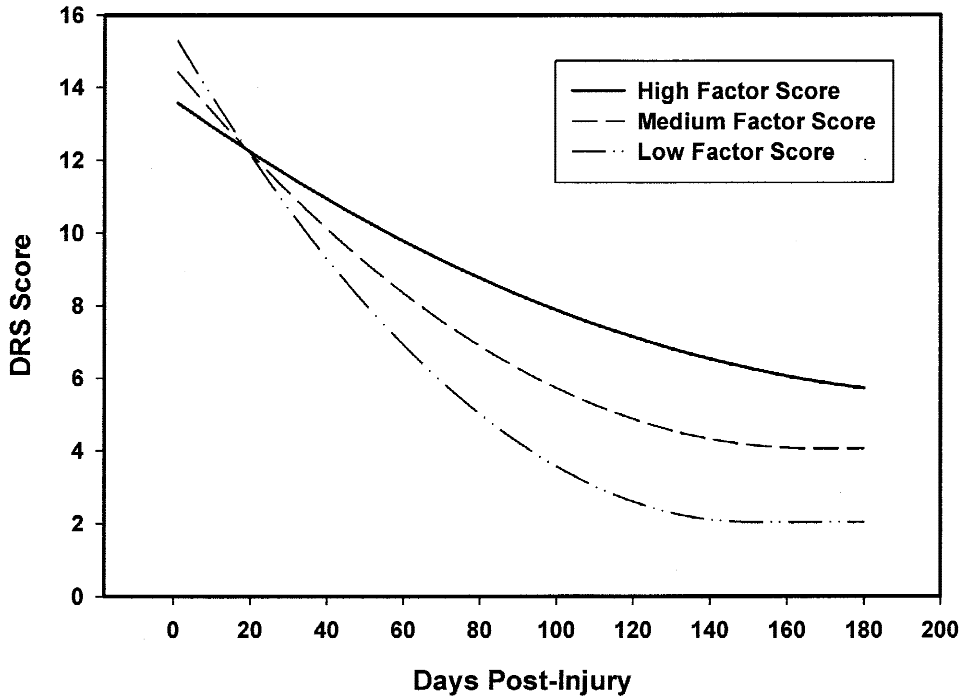

Fig. 4. *Recovery curves for high, medium, and low values of cognitive burden*: This figure demonstrates the DRS recovery curves based on the growth curve parameter estimates listed in Table 3 for Cognitive Burden. Quicker rate of recovery is associated with a lesser degree of SO-reported burden as a result of cognitive deficits at 6 months.

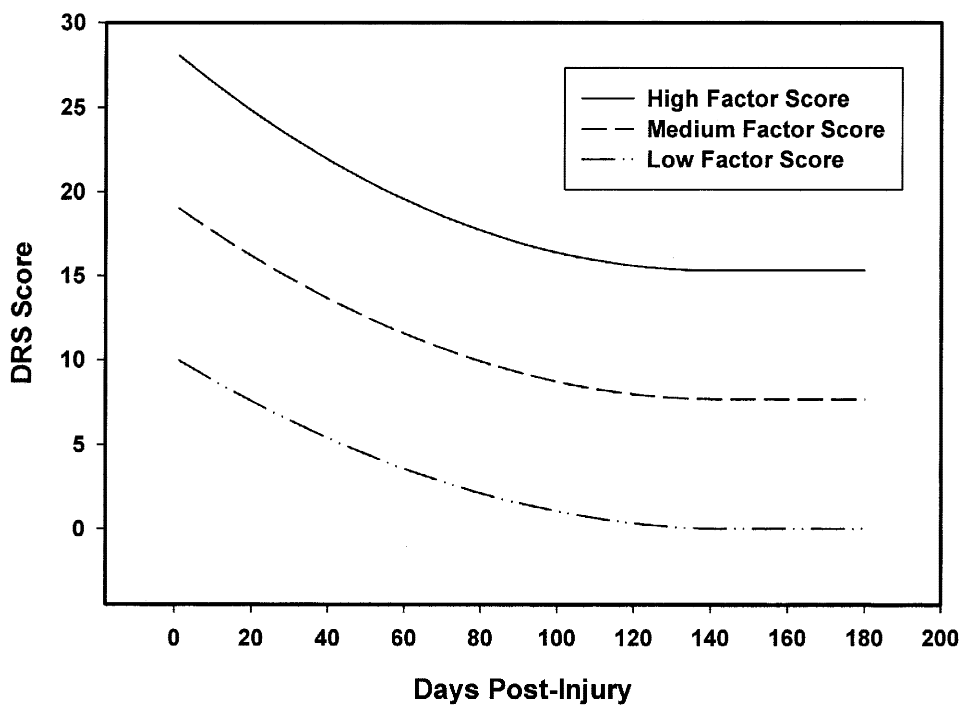

Fig. 5. *Recovery curves for high, medium, and low values of physical/dependency severity*: This figure depicts the DRS recovery curves based on the parameter estimates listed in Table 3 for the severity of SO-reported Physical/Dependency symptoms. This outcome domain at 6 months is associated with the acute level of the DRS and not the shape of the DRS recovery curve.

for perceptions of physical/dependency status 6 months post injury, not the patient's rate of recovery.

DISCUSSION

Fleming and Maas (1994) were the first to report on a technique that utilized the rate of change in the DRS to investigate outcome. Building on the clinician's informal method of predicting outcome based on more rapid recovery being associated with better outcome and the findings of Fleming and Maas, the current study took the next step in exploring this concept with a more sophisticated statistical method.

An interesting result of this study was the very robust association between the SO's perception of physical/dependency issues (both severity and burden) with a component of the DRS recovery curve, namely the level at 1 month post injury. This warrants further conceptualization and discussion. When considering the rating of the items of the DRS, physical impairments of the patient are minimized. For example, the scoring criteria for the feeding, toileting, and grooming items specifically state that physical ability is to be ignored; it is the patient's *cognitive* ability (or general awareness) of when to perform these activities that is measured. Only the Level of Functioning and Employability items of the DRS take into account the patient's physical abilities. These items also include the level of supervision needed (dependency). It is possible that the *dependency* needs that these patients demonstrated (or the SO-perceived) were more strongly associated with the DRS curve centered at 30 days as more of these items were included in the physical/dependency factor score of the NYU-HIFI.

It would appear reasonable to speculate that issues regarding *dependency* (e.g., need for supervision, sense of dependency on others, lack of initiative, poor balance, doing things more slowly, etc.) are likely to prevent one from successfully returning to work or other preinjury activities at, or near, a premorbid level. However, it is also reasonable to expect that emotional and, to some extent cognitive difficulties, would be more likely to prevent a patient from resuming more normal daily functioning or return to work than dependency issues (Brooks, 1984; Brooks & McKinlay, 1983; Brooks et al., 1984, 1986, 1987; McKinlay et al., 1981). These cognitive and emotional symptoms may place a greater burden on the emotional resources of the family members as well. Indeed, what the growth curve analyses of the physical/dependency variables have delineated is that rate of recovery is not strongly associated with the SO's perception of physical/dependency; only the *level* (intercept) of the DRS at 30 days post injury (indeed at every point) is strongly associated with this outcome. For this specific outcome domain, equally good predictions of future status could have been made with an acute DRS score as with the six month DRS recovery curve.

Probably the most interesting finding of this study was the strong relation between the DRS recovery curve and the severity of SO-perceived cognitive deficits. The relation between the DRS recovery curve and high, medium, and low levels of SO-perceived cognitive deficit severity are depicted in Figure 3; flatter rates of recovery portend higher levels of reported cognitive difficulties. This compellingly illustrates the principle that the more rapid the recovery, the milder the severity and burden of reported cognitive deficits at 6 months post injury. In this case, the results from growth curve modeling of severity and burden is better predicted by the 6-month DRS recovery curve rather than a single acute DRS score.

It is clear that in this study, one regression technique may lead to a very different conclusion compared to the other. Indeed, if one relied solely on correlations (e.g., rehabilitation admission and discharge DRS scores), one would have missed the very information needed for determining future SO-perceived cognitive severity and burden (for example) which could be determined from the slope and curvilinearity of the DRS recovery curve. This example points out clearly a weakness in using a correlational (simple regression) approach alone in investigating predictors of outcome; it is not only the initial DRS score that is predictive of outcome, but the changes in the rate of change (curvilinearity) that also is important. It would appear that on balance, much more can be gained from growth curve analyses than with correlation analyses alone. A simple correlation may yield a sign that a strong relation exists, but the truly interesting and important information remains to be uncovered.

The preceding results provide information about the DRS that has not been presented previously in the literature. Prior studies have often relied on the DRS as both predictor and criterion leaving virtually all other outcome criteria unconsidered (Fleming & Maas, 1994; Fryer & Haffey, 1987; Giancino et al., 1987; Hedrick et al., 1995; Ponsford et al., 1995; Rao & Kilgore, 1992; Rappaport et al., 1989a; Thatcher et al., 1991). For the first time, it has been demonstrated that the DRS may be more predictive of certain dimensions of outcome (i.e., cognitive severity *vs.* affective/neurobehavioral burden) than others, as perceived by SOs. This has important implications for the preparation of families and planning for rehabilitation programs. In this study, not only was the slope found to be significantly correlated with measures of SO-perceived outcome at 6 months, but the rate at which recovery reached asymptote was found to be very significantly related to certain measures of outcome. This likely will be helpful in providing families with a better estimate of eventual outcome earlier in the acute phase than had been possible in the past.

More is now understood about the relation between outcome and the rate of recovery over time. As Boake and High (1996) indicated, outcome from head injury is multidimensional and not adequately captured by unidimensional measures. Clearly the results from this study have indicated that different domains of outcome have different relations with the rate of recovery beyond the *level* of recovery at any one point in time. Future models of the relations between predictor and criterion outcome variables should consider the complexity between these measures to more fully exploit the information they contain.

Some limitations need to be examined with regard to this study. Our sample size was not particularly large. However, studies of the DRS have reported sample sizes from 27 to 266 (*MDN* = 75; Fleming & Maas, 1994; Fryer & Haffey, 1987; Giancino et al., 1991; Gouvier et al., 1987; Hall et al., 1985; Malec & Thompson, 1994; Rao & Kilgore, 1992; Rappaport et al., 1977, 1981, 1982, 1989a, 1989b, 1990, 1991; Thatcher et al., 1991). Measures such as the GOS and DRS continue to be primary outcome measures for clinical trials because of the relative ease with which they can be collected and the willingness of the patients and family members to participate in studies using these measures. In contrast, it often proves quite difficult to obtain neuropsychological measures of outcome from the patient and to complete structured interviews with the patient and the family at only 6 months post injury. For instance, Scheibel et al. (1998) reported only a 52% completion rate of a small battery of neuropsychological tests at 6 months post injury in a multicenter clinical trial of severe head injury. Participants were provided remuneration for their participation and had examiners travel to the patient in order to complete testing, out of state if necessary. Our completion rate compares favorably with 56.5% of patients completing the NYU-HIFI (at least) at 6 months without reimbursement. For this reason it is very important to continue to investigate the efficacy of measures of the DRS and GOS. We will continue to collect this data over the next 5 years after which time a replication study will be conducted with a larger sample.

The results of any study are necessarily limited by the validity and reliability of the measures employed. A fair amount is known about the reliability, and to some extent, the validity of the DRS. However, more data is needed for the NYU-HIFI. This paper has investigated the relation between the DRS and the NYU-HIFI measures. Further validation with other criterion measures is planned. Future studies should employ neuropsychological tests to determine whether the rate of recovery significantly predicts neuropsychological test performance. Other future studies using DRS recovery curves, such as predicting return to work or return to independent living status, are currently being planned.

CONCLUSION

Growth curve modeling has demonstrated that the rate of recovery is indeed an important determinant of specific psychosocial outcomes, from the SO's perspective, with regard to the severity of affective/neurobehavioral disturbance, and the severity and burden of perceived cognitive deficits at 6 months post injury. The SO's perspective of the physical/dependency status of the patient does not appear to be influenced by the rate of recovery as measured by the DRS, but instead by an acute DRS level. The authors have presented a methodology that will allow the clinician to make better predictions of family-relevant psychosocial outcome based on DRS recovery curves. In future studies, this methodology could also be used to test family interventions designed to minimize specific types of subjective burden that families report experiencing following head injury.

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REFERENCES

Boake, C. & High, W.M. (1996). Functional outcome from traumatic brain injury: Unidimensional or multidimensional? *American Journal of Physical Medicine and Rehabilitation*, *75*, 105–113.

Brooks, D.N. (1984). *Closed head injury: Psychological, social, and family consequences*. New York: Oxford University Press.

Brooks, D.N., Campsie, L., & Symington, C. (1986). The 5 year outcome of severe blunt head injury: A relative's view. *Journal of Neurology, Neurosurgery, and Psychiatry*, *49*, 764–770.

Brooks, D.N., Campsie, L., & Symington, C. (1987). The effects of severe head injury on patient and relative within 7 years of injury. *Journal of Head Trauma Rehabilitation*, *2*, 1–13.

Brooks, D.N., Deelman, B.G., van Zomeren, A.H., van Dongen, H., van Harskamp, F., & Aughton, M.E. (1984). Problems in measuring cognitive recovery after acute brain injury. *Journal of Clinical Neuropsychology*, *6*, 71–85.

Brooks, D.N. & McKinlay, W.W. (1983). Personality and behavioral change after blunt head injury: A relative's view. *Journal of Neurology, Neurosurgery, and Psychiatry*, *46*, 336–344.

Bryk, A.S. & Raudenbush, S.W. (1987a). Application of hierarchical linear models to assessing change. *Psychological Bulletin*, *101*, 147–158.

Bryk, A.S. & Raudenbush, S.W. (1987b). *Hierarchical linear models: Applications and data analysis methods*. Newbury Park, CA: Sage Publications.

Cavallo, M.M., Kay, T., & Ezrachi, O. (1992). Problems and changes after traumatic brain injury: Differing perceptions within and between families. *Brain Injury*, *6*, 327–335.

Clifton, G.L., Hayes, R.L., Levin, H.S., Michel, M.E., & Choi, S.C. (1992). Outcome measures for clinical trials involving traumatically brain-injured patients: Report of a conference. *Neurosurgery*, *31*, 975–978.

Eliason, M.R. & Topp, B.W. (1984). Predictive validity of Rappaport's Disability Rating Scale in subjects with acute brain dysfunction. *Physical Therapy*, *64*, 1357–1360.

Fleming, J.M. & Maas, F. (1994). Prognosis of rehabilitation outcome in head injury using the Disability Rating Scale. *Archives of Physical Medicine and Rehabilitation*, *75*, 156–163.

Francis, D.J., Fletcher, J.M., Stuebing, K.K., Davidson, K.C., & Thompson NM. (1991). Analysis of change: Modeling individual growth. *Journal of Consulting and Clinical Psychology*, *59*, 27–37.

Francis, D.J., Shaywitz, S.E., Stuebing, K.K., Shaywitz, B.A., & Fletcher, J.M. (1996). Developmental lag versus deficit models of reading disability: A longitudinal individual growth curve analysis. *Journal of Educational Psychology*, *88*, 3–17.

Fryer, L.J. & Haffey, W.J. (1987). Cognitive rehabilitation and community readaptation: Outcomes from two program models. *Journal of Head Trauma Rehabilitation*, *2*, 51–63.

Giancino, J.T., Kezmarsky, M.A., DeLuca, J., & Cicerone, K.D. (1991). Monitoring rate of recovery to predict outcome in minimally responsive patients. *Archives of Physical Medicine and Rehabilitation*, *72*, 897–901.

Gouvier, W.D., Blanton, P.D., LaPorte, K.K., & Nepomuceno, C. (1987). Reliability and validity of the Disability Rating Scale and Levels of Cognitive Functioning Scale in monitoring recovery from severe head injury. *Archives of Physical Medicine and Rehabilitation 1987*, *68*, 94–97.

Hall, K., Cope, D.N., & Rappaport, M. (1985). Glasgow Outcome Scale and Disability Rating Scale: Comparative usefulness in following recovery in traumatic head injury. *Archives of Physical Medicine and Rehabilitation*, *66*, 35–37.

Hall, K.M., Hamilton, B.B., Gordon, W.A., & Zasler, N.D. (1993). Characteristics and comparisons of functional assessment indices: Disability Rating Scale, Functional Independence Measure, and Functional Assessment Measure. *Journal of Head Trauma Rehabilitation*, *8*, 60–74.

Hedrick, W.P., Pickelman, H.L., & Walker, W. (1995). Analysis of demographic and functional subacute (transitional) rehabilitation data. *Brain Injury*, *9*, 563–573.

Jennett, B. & Bond, M. (1975). Assessment of outcome after severe head injury. *Lancet 1*, *7905*, 480–487.

Kay, T., Cavallo, M.M., Ezrachi, O., & Vavagiakis, P. (1995). The Head Injury Family Interview: A clinical and research tool. *Journal of Head Trauma Rehabilitation*, *10*, 12–31.

Kreutzer, J.S., Gervasio, A.H., & Camplair, P.S. (1994a). Primary caregivers' psychological status and family functioning after traumatic brain injury. *Brain Injury*, *8*, 197–210.

Kreutzer, J.S., Gervasio, A.H., & Camplair, P.S. (1994b). Patient correlates of caregivers' distress and family functioning after traumatic brain injury. *Brain Injury*, *8*, 211–230.

Kreutzer, J.S., Marwitz, J.H., & Kepler, K. (1992). Traumatic brain injury: Family response and outcome. *Archives of Physical Medicine and Rehabilitation*, *73*, 771–778.

Kreutzer, J.S., Serio, C.D., & Bergquist, S. (1994c). Family needs after brain injury: A quantitative analysis. *Journal of Head Trauma Rehabilitation*, *9*, 104–115.

Leaf, L.E. (1993). Traumatic brain injury: Affecting family recovery. *Brain Injury*, *7*, 543–546.

Lezak, M.J. (1978). Living with the characterologically altered brain injured patient. *Journal of Clinical Psychiatry*, *39*, 592–598.

Lezak, M.J. (1988). Brain damage is a family affair. *Journal of Clinical and Experimental Neuropsychology*, *10*, 111–123.

Malec, J.F. & Thompson, J.M. (1994). Relationship of the Mayo-Portland Adaptability Inventory to functional outcome and cognitive performance measures. *Journal of Head Trauma Rehabilitation*, *9*, 1–15.

McKinlay, W.W., Brooks, D.N., Bond, M.R., Martinage, D.P., & Marshall, M.M. (1981). The short-term outcome of severe blunt head injury as reported by relatives of the injured persons. *Journal of Neurology, Neurosurgery, and Psychiatry*, *44*, 527–533.

Oddy, M., Humphrey, M., & Uttley, D. (1978a). Stresses upon the relatives of head-injured patients. *British Journal of Psychiatry*, *133*, 507–513.

Oddy, M., Humphrey, M., & Uttley, D. (1978b). Subjective impairment and social recovery after closed head injury. *Journal of Neurology, Neurosurgery, and Psychiatry*, *41*, 611–616.

Ponsford, J.L., Olver, J.H., Curran, C., & Ng, K. (1995). Prediction of employment status 2 years after traumatic brain injury. *Brain Injury*, *9*, 11–20.

Rao, N. & Kilgore, K.M. (1992). Predicting return to work in traumatic brain injury using assessment scales. *Archives of Physical Medicine and Rehabilitation*, *73*, 911–916.

Rappaport, M. (1986). Brain evoked potentials in coma and the vegetative state. *Journal of Head Trauma Rehabilitation*, *1*, 15–29.

Rappaport, M., Hall, K., Hopkins, K., & Belleza, T. (1981). Evoked potential and head injury 1. Rating of evoked potential abnormality. *Clinical Electroencephalography*, *12*, 154–166.

Rappaport, M., Hall, K., Hopkins, K., Belleza, T., Berrol, S., & Reynolds, G. (1977). Evoked potentials and disability in brain-damaged patients. *Archives of Physical Medicine and Rehabilitation*, *58*, 333–338.

Rappaport, M., Hall, K., Hopkins, K., Belleza, T., & Cope, D.N. (1982). Disability Rating Scale for severe head trauma: Coma to community. *Archives of Physical Medicine and Rehabilitation*, *63*, 118–123.

Rappaport, M., Hemmerle, A.V., & Rappaport, M.L. (1990). Intermediate and long latency SEPs in relation to clinical disability in traumatic brain injury patients. *Clinical Electroencephalography*, *21*, 188–191.

Rappaport, M., Hemmerle, A.V., & Rappaport, M.L. (1991). Short and long latency evoked potentials in traumatic brain injury. *Clinical Electroencephalography*, *22*, 199–202.

Rappaport, M., Herrero-Backe, C., Rappaport, M.L., & Winterfield, K.M. (1989b). Head injury outcome up to ten years later. *Archives of Physical Medicine and Rehabilitation*, *70*, 885–892.

Rappaport, M., Herrero-Backe, C., Winterfield, K.M., Rappaport, M.L., & Hemmerle, A.V. (1989a). Visual evoked potential pattern abnormalities and disability in severe traumatically brain-injured patients. *Journal of Head Trauma Rehabilitation*, *4*, 45–52.

Rosenbaum, M. & Najenson, T. (1976). Changes in life patterns and symptoms of low mood as reported by wives of severely brain-injured soldiers. *Journal of Consulting and Clinical Psychology*, *44*, 881–888.

Scheibel, R., Levin, H.S., & Clifton, G.L. (1998). Completion rates and feasibility of outcome measures: Experience in a multicenter trial of systemic hypothermia for severe head injury. *Journal of Neurotrauma*, *15*, 685–692.

Schentzel, S.J. (1993). *The relation of the Halstead-Reitan Neuropsychological Test Battery and the NYU Head Injury Family Interview to the nature of family burden following traumatic brain injury*. Unpublished doctoral dissertation, Walden University, Chicago.

Thatcher, R.W., Cantor, D.S., McAlaster, R., Gleiser, F., & Krause, P. (1991). Comprehensive predictions of outcome in closed-head injured patients: The development of prognostic equations. *Annals of the New York Academy of Sciences*, *620*, 82–101.

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