AN ABSTRACT OF THE DISSERTATION OF

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The study explored various musculoskeletal, neuromuscular and psychological impairments constraining the movement capabilities of adults with multiple sclerosis (MS). Specifically, the variability within each constraint and the relationship between individual constraints and functional competence in activities of daily living were examined. Five adults with MS (X=44 years) were assessed on muscular strength in the lower extremities, upright postural control, mood, fatigue, self-efficacy, and stress. In addition, functional competence in daily life activities was evaluated using the Scale of Functional Competence in Multiple Sclerosis (SFCMS). The scale was developed to assess each participant's ability to 1) step up onto a 6 inch wooden riser, 2) reach for a cup placed above head-height, and 3) walk 12 feet while carrying a bag of groceries. Preliminary data suggest that the SFCMS had the potential to sufficiently measure the functional competence in these three tasks of daily living for individuals with MS. P-technique factor analyses were first performed to discover covariation patterns among the variables over a four month period. While identifiable covariation patterns were observed for four of the five participants, no commonalties in factor patterns were found across the sample. Further, correlational procedures failed to demonstrate any strong relationships between physical and psychological variables nor between these variables and functional performance. Lastly, the extent of variability observed was then quantified through coefficients of variation. Results indicated that, for all five

participants, fatigue and stress fluctuated the greatest over the 16 week period. Most importantly, variability in both the physical and psychological variables was shown to be much greater than variability observed in performance of the functional tasks. An ecological interpretation was offered to explain the preservation of functional competence in activities of daily living in light of fluctuating constraints. Future research employing an ideographic approach to examine intraindividual variability in adults with MS may prove beneficial in affording a deeper understanding of how disease-related constraints influence functional performance. Additionally, research quantifying the extent of variability in particular constraints may afford clinicians and researchers greater insight and accuracy when assessing functional status and therapeutic outcomes in individuals with MS.

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Constraints on Functional Competence in Persons with Multiple Sclerosis

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Susan L. Kasser

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Susan L. Kasser, Author

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INTRODUCTION

Physical impairments and symptoms associated with neurologic disorders have considerable impact on the ability to perform daily personal, professional, and household-related tasks. In many cases, such deficits often result in markedly decreased activity levels and subsequent dependence on others for everyday activities. The functional disability which results also has serious consequences for the health and quality of life for each of these individuals (Fuhrer, 1994; Lundmark & Branholm, 1996). In response to this pressing issue, both clinicians and researchers have focused their attention on understanding how individuals control their movements and how disease-related impairments, such as those associated with multiple sclerosis, influence the effective performance of daily life activities.

Constraints Underlying Functional Performance in MS

Due to the extent and gravity of disease-related symptoms on daily life activities, multiple sclerosis (MS) has been ranked among the top chronic health conditions affecting young adults today (National Center for Health Statistics, 1986). MS is a neurological disease of the central nervous system (CNS) that often imposes serious physiological and psychological consequences for the individual. Due to the extreme fluctuations and unpredictability of the disease, individuals face each day with uncertainty as to how well they are able to complete tasks of daily living. Motor and balance dysfunction can also be significant enough to increase susceptibility to falls and result in functional dependence (Tideiksaar & Kay, 1986).

A number of impairments which impact the movement capabilities of adults with MS have been documented. In fact, scientific research has provided evidence of multiple musculoskeletal, neuromuscular and psychological impairments which serve to constrain movement and effect the functional ability of adults with the disease. Decreased muscular strength in the lower extremities has been reported for individuals with MS compared to healthy adults (Armstrong, Winant, Swasey, Seidle, Carter, & Gehlsen, 1983; Chen, Pierson, & Burnett, 1987; Ponichtera, Rodgers, Glaser, Mathews, & Camione, 1992). In addition, sensory interaction deficits and vestibular dysfunction (Herrera, 1990; Nelson, Di Fabio, & Anderson, 1994) as well as the latency of postural responses (Pratt, Horak, & Herndon, 1992; Diener, Dichgans, Hulser, Buettner, Bacher, & Guschlbauer, 1984) have been demonstrated. Persons with MS also experience substantial fatigue which seriously impacts balance and daily function (Freal, Kraft, Coryell, 1984; Vercoulen et al., 1996). Spasticity, commonly associated with the disease, has further serious negative consequences for the functional mobility and competence of these individuals (Chan, Hugos, Morrison, & Theriot, 1994).

Along with physiological and neurological constraints imposed upon an individual by MS, there are also reports of altered psychological responses. Symptoms of severe fatigue, depression, and stress have all been well-recognized in adults with the disease (Mendez, 1995; Zeldow & Pavlou, 1984). Mood fluctuations have likewise been associated with changes in disease status and physical health (Gatten, Brookings, and Bolton, 1993). Yet, Minden and Schiffer (1990) contend that too little attention has been paid to the emotional and affective aspects of the disease. Only recently has subjective well-being and mood state been included in examination of life satisfaction in this population (Cella et al., 1996; Wineman, Schwetz, Goodkin, & Rudick, 1996). While the psychological aspects associated with MS have been acknowledged, these constraints have not been examined in relation to specific physiological changes. Other than general ambulation status, affect and emotion have seldom been linked to physical constraints such as weakness and balance dysfunction. How these physical constraints relate to or influence psychological status in this population remains unclear. To understand more about the psychological impact of the disease, Devins and Seland (1987) advocate for employing longitudinal designs to examine variations in emotional well-being across periods of relapse and remission.

While physiological, neurological, and psychological factors constraining the mobility and balance capabilities of these individuals have been delineated, quantification of variability within and across these constraints remains undocumented. Further, little empirical research has explored how specific constraints - either singularly or in combination - impact performance of functional tasks (Peyser, Rao, LaRocca, & Kaplan, 1990; Ponichtera-Mulcare, 1993).

Ecological Approaches to Movement Dysfunction

In explaining the emergence of and variability in movement responses in persons with MS, recent approaches to motor control may hold promise. An ecological perspective emphasizes the interaction of the person and the environment during everyday functional tasks (Gibson, 1979; Reed, 1982). Rather than viewing movement as simply the outcome of an individual's capabilities, it is also considered in view of the context and the specifics of the task. The movement pattern that is used to accomplish daily tasks emerges as a consequence of the interacting constraints and, in actuality, reflects the most functional movement of the individual (Kugler, Kelso, & Turvey, 1980). In fact, a number of constraints interact and influence the way in which each person carries out everyday activities (Newell, 1986). Biomechanical, physiological, neuromuscular, and psychological changes due to disease can all contribute to limitations in performance (Holt, 1993). It is apparent that a variety of person-related constraints come together to influence the movements used by an individual with MS to perform daily activities. These individual constraints are also most relevant to the study of MS given their extreme fluctuations and impact on functional ability. Despite this realization, constraints are typically not examined together or viewed in relation to functional outcomes.

Based upon this contemporary approach to motor control, the relations between components of the system and the variability that exists within different systems are important dimensions of movement. While variability in movement was previously viewed as negative, both from an empirical and clinical standpoint, the proposition that this variability is potentially positive and the adaptive function it serves are important distinctions of this theoretical perspective (Newell & Corcos, 1993). Movement can change as either the individual, the environment, or the task changes in order to adapt and preserve the functional outcome for the individual. However, movements that still serve a functional end need not change even as constraints vary (McGinnis & Newell, 1982; Riccio & Stoffregen, 1988). In this case, movement is considered "insensitive to functionally inconsequential variations" in the individual, the environment, and the task (Riccio, 1993, p. 321).

The ability of the system to adapt to changing constraints and to afford functional movement are important dimensions for understanding functional competence in daily activities. Riccio (1993) contends that a research program that demonstrates the functional role of movement variability by examining the relationships between properties of the individual and variability in movement patterns is needed. While this theoretical perspective may also provide a better understanding of movement dysfunction - including that related to MS - Wagenaar & van Emmerick (1996) claim that relatively few studies have adopted this approach.

Measurement of Functional Performance in MS

Since there is a compelling need to develop therapeutic interventions that maintain physical capacities and foster functional ability in those with MS, it is critical to understand to what extent physical capabilities and emotional status interact and are problematic. It is just as important to ascertain to what degree associated deficits restrict functional performance. The development and use of standardized scales to evaluate the functional status of individuals with MS is critical to this end.

A variety of scales have been used in the evaluation of basic functional abilities and level of independence required to perform functional tasks in adults with MS. Some scales, while not developed specifically for this population, have been used to assess functional performance. For example, the Barthel Index, Functional Independence Measure (FIM), and other global activities of daily living (ADL) tools have been employed in studies of MS. Granger and colleagues (1990) previously examined the impact of disability on the lives of individuals with MS by using a combination of functional assessment scales. Results of their investigation revealed the FIM to be more precise and predictive of patients' physical and psychological needs and general level of satisfaction with life than the other measures employed.

The Minimal Record of Disability (MRD), developed solely for the purpose of measuring physical capacity and environmental handicaps experienced by individuals with the disease, has served as the most common measurement instrument. The MRD organizes demographic, neurologic, functional, and psychological data in a standardized and objective manner. A more recent evaluative tool, the Functional Model in MS (Halper, 1990), extends the utility of the MRD by emphasizing function rather than dysfunction and including the individual's self-reported level of functional independence in activities of daily living.

While the development of functional scales have improved descriptions of functional status in adults with MS, their inability to detect subtle changes in performance capabilities remains problematic (Schwartz, Cole, & Gelber, 1995).

As well, summary scales often fail to provide information detailing how deficits associated with disease differentially impact the functional performance of ADL tasks. Thus, these instruments may limit insight into potential relationships between individual constraints and functional outcomes (Fisher, 1993; Fried, Ettinger, Lind, Newman, & Gardin, 1994). Doble and colleagues (1994) further claim that these measurements have typically centered on general mobility capabilities or general level of independence rather than specific tasks which may be more meaningful and relevant to the individual. If health care providers are to accurately document changes in the functional status of their clientele as a result of therapeutic intervention, assessment instruments which precisely describe functional capabilities and specify functional changes must first be developed and then routinely employed.

Research Methodology Related to Individuals with Neurological Dysfunction

In rehabilitation settings, health care providers often work one-on-one with individual clients in an attempt to optimize the functional capabilities of these individuals. Despite this individualized approach to clinical practice, research assessing patient functioning and/or the efficacy of therapeutic interventions has traditionally been conducted with groups of individuals (Worthington, 1995). The need to provide clinically meaningful information about therapeutic interventions obliges the adoption of experimental approaches where the uniqueness of individuals is considered (Ottenbacher, 1986). Single case experimental designs have been forwarded as a means by which to bridge the gap between science and therapeutic practice and, as a result, may encourage greater communication and collaboration between the researcher and therapist (Figoni, 1990).

From a statistical standpoint, inferences and subsequent generalizations made from group data are only warranted when subjects in the group are functionally homogeneous (Bouffard, 1993). Assumptions underlying parametric group data analysis cannot always be met when consideration is given to intraindividual differences and interindividual variability within a particular population. The rationale for using single subject designs is based on individual uniqueness and the varying functional characteristics and heterogeneity of some groups as well as the notion that mean values for a group may represent very few of the individuals involved. It may be argued that the single case approach can only explain the behavior of a limited sample of people and that group designs are necessary to establish the broader clinical utility of specific procedures. Yet, from a practical perspective, clinical or therapeutic significance must be prioritized as a more important goal of empirical investigations than statistical significance. Bouffard (1993) further contends that single case designs should be selected on the basis of specific research questions and underlying theoretical foundations rather than on traditional research practices or the limited availability of subjects.

Because of the heterogeneity of disabling conditions, it is essential that researchers reinstate the person as the basic unit of analysis (Bouffard, 1993). In this way, interindividual and intraindividual differences are not viewed as nuisances but rather as sources of important information. The heterogeneity of specific groups - including adults with multiple sclerosis - support the use of experimental single case designs. These designs are invaluable for investigating changes in behavior within and across individuals. As well, they provide a powerful method for assessing the constraints that impact functional competence in various daily life activities. The degree of pathological differences across individuals with MS and the unpredictability and variability of clinical manifestations of the disease render investigations using cross-sectional group designs questionable. Problems of decreased sample size, attrition, and individual patterns of change further challenge descriptions using conventional measures (Kazdin, 1983). As a result, an ideographic approach which focuses on the uniqueness of each individual is recommended for clinically applicable research (Ottenbacher, 1992).

General Study Aims

The present study examined physiological and psychological constraints that contribute to the movement responses and functional competence of individuals with multiple sclerosis. Specifically, the study explored 1) the extent to which variability in intrinsic factors impacted observable performance of activities of daily life and 2) whether the nature and extent of these changes in individual constraints was similar across adults with the disease. The study included a four-month longitudinal assessment of strength, limits of stability, standing postural control, mood, self-efficacy to perform activities of daily living (ADL), along with an evaluation of the functional performance of these tasks. Five individuals diagnosed with multiple sclerosis between 37-50 years of age were involved in the study.

Significance of the Study

The preceding overview offers the theoretical foundation and conceptual approach to the study. The significance of using an ideographic approach and quasi-longitudinal research design is based upon the extreme heterogeneity of the population and the lack of empirical documentation of the nature and impact of intrinsic factors on functional competence in adults with MS. Despite the assertion of extreme variability in this population (Schapiro, 1991), empirical examination of the variability and stability of factors underlying performance in individuals has been relatively undocumented. Assessment of constraints on mobility and functional performance have been limited to single measurements in time and have failed to acknowledge the diversity of the group. Additionally, while common scales of neurologic function (e.g., the Expanded Disability Status Scale) describe the effects of the disease on ambulation and bodily functions, they fail to provide objective criteria on how symptoms might translate into actual loss of functional ability (Hohol, Orav, & Weiner, 1995). The functional consequences of variations in physical and psychological constraints in terms of activities of daily living also remain unexamined.

Measurement of individual functioning must relate not only to evaluation of important individual constraints but, as well, to how these constraints underlying performance capabilities interact and vary over time. Unfortunately, the limited amount of information regarding disease-related constraints and their effect on functional behavior over time make decisions regarding therapeutic interventions and development of specific guidelines difficult at best. Maintenance of independent functioning in adults with MS necessitates a clear understanding of which and in what ways physical and psychological constraints impact functional performance. As well, the lack of scientific data regarding variability in disease-related factors and functional ability of persons with MS over a specific period of time serves to perpetuate misinformation regarding the impact of the disease and hinder effective therapeutic progress. To gain a more comprehensive understanding of the functional issues facing these individuals, the underlying constraints and day-to-day variability that impacts functional performance over time must be examined. The present study provides some needed insight in this regard. The inclusion of a sample of participants with MS allowed for comparison of these constraints and, more importantly, discovery of possible similarities in the variability and function observed.

Chapter 2

The Scale of Functional Competence in Multiple Sclerosis: Validity and Reliability

Susan L. Kasser

Abstract

The Scale of Functional Competence in Multiple Sclerosis (SFCMS) was developed and examined for validity and reliability in ten adults with MS (48.6$\pm$6.9 years). Each participant completed three trials of 1) stepping up onto a 6 inch wooden riser, 2) reaching for a cup placed above head-height, and 3) walking 12 feet while carrying a bag of groceries. Two independent judges rated participants using the SFCMS, while a third ranked subjects, from most to least competent, based on professional judgment. Development of the scale ensured content validity by including input from both clinicians and individuals with MS. Intraclass coefficients revealed high interrater reliability for the stepping task (r = 1.0) and the reaching task (r = .98) and moderate reliability for the walking task (r = .73). Intrarater reliability was also moderate to high with intraclass coefficients of .86, .87, and .97 for the reaching, walking, and stepping tasks respectively. Spearman rho correlations between expert rankings and scale-based rankings demonstrated good evidence of concurrent validity for the task of stepping (r = .94) and the reaching task (r = .76). The walking task, however, failed to demonstrate good evidence of concurrent validity (r = .41). Restriction in range of scale-based rankings, as compared to expert rankings of competency, was offered as a possible explanation for the lower validity coefficients. The preliminary data suggests that the SFCMS has the potential to satisfactorily measure the functional competence in three tasks of daily living for adults with MS. Future research to validate the scale should include increasing sample size, operationally defining or clarifying scale items, and employing additional experts as raters. The instrument may have important clinical utility in measuring functional changes related to disease progression or functional outcomes following therapeutic intervention in this population.

Introduction

In the past, treatment techniques for individuals with neurologic conditions typically targeted specific impairments underlying movement dysfunction. Consequently, rehabilitation goals were primarily aimed at improving impairment-based deficits such as reducing spasticity or promoting symmetry of the gait pattern. This widespread approach to adult rehabilitation firmly rested on the assumption that normalization of movement and movement patterns would automatically translate into improved function in activities of daily living (ADLs) (Gordon, 1987). Unfortunately, knowledge based on assessment of specific and isolated impairments did little to afford insight into clinically meaningful estimations of functional performance.

Recently, there has been a shift from focusing on quantitative and qualitative changes of independent deficits toward greater emphasis on the functional consequences and significance of such changes (Harris, 1991). How specific impairments translate into the actual loss of functional ability and the subsequent development of functionally oriented treatment goals have now become the basis of neurologic rehabilitation. Clinicians responsible for implementing treatment plans that improve the daily functioning and independence of individuals with neurological disorders must, therefore, be able to objectively and accurately assess functional performance. Despite the acknowledgment of measuring functional outcomes, a number of significant issues remain as clinicians and researchers attempt to include functionally relevant measures in their work. For one, most existing ADL assessments have not been standardized or lack psychometrics specific to particular patient populations (Bernspang & Fisher, 1995). Beyond this, ADL scales typically evaluate a number of different tasks in an effort to obtain a summed total score. The problem with this approach rests with the underlying assumption that a total score represents or quantifies a person's overall ADL ability

(Fisher, 1993). While these summary scales routinely include activities which are similar in that they relate to general daily living skills, they in fact clinically rely on a diversified combination of physiological abilities and psychological underpinnings for their performance (Fisher, 1993; Fried, Ettinger, Lind, Newman, & Gardin, 1994). Such an approach may limit insight into the possible relationships between individual impairments and performance of daily tasks.

Among those adults diagnosed with MS, a variety of impairments have been identified. Some degree of functional disability and loss of independence in activities of daily living is also common (Lundmark & Branholm, 1996). The development and use of standardized scales to evaluate the functional status of these individuals is a necessary step in determining the need for rehabilitation services and/or clinically monitoring changes in function as a result of disease progression or intervention.

Traditional scales for assessment in MS have routinely emphasized the measurement of anatomical, physiological, or psychological impairment. Other scales claiming to differentiate among functional stages of MS or assess level of disability fail to sufficiently assess how particular deficits translate into loss of functional competence in daily life activities (Peyser, Rao, LaRocca, & Kaplan, 1990; Ponichtera-Mulcare, 1993). In fact, when functional limitations are viewed in light of disability status (i.e., Expanded Disability Status Score - EDSS), only those with severe disability evidence dysfunction in performance of ADLs (Cohen, Kessler, & Fischer, 1993). Difficulty in assessing functional changes associated with MS arises from continued use of scales that are insensitive, unreliable, and subjective (Hohol, Orav, & Weiner, 1995; Willoughby & Paty, 1988). The Minimal Record of Disability (MRD), while a more objective and comprehensive functional scale for MS, still remains plagued by insensitivity to detect subtle changes in performance and offers only an overall score to represent diverse functional activities. Even Halper's (1990) Functional Model in MS, which extends the MRD to include self-reported details of functional dependence in activities of daily living, overlooks the specificity and quality of the movement outcome.

In order for clinicians to accurately reflect functional changes and be assured that treatment programs are efficacious in improving functional competence in activities of daily life, it is necessary to have available assessment instruments that are functional in nature, include specific and observable aspects of levels of independence, and focus on process as well as product related components of performance. These issues and an increasing awareness of the limitations of traditional scales underscore the importance of developing valid, reliable, and sensitive instruments by which to directly assess the functional status of adults with MS. Moreover, the development of a functional assessment which is geared to specific ADL tasks is also warranted. The purpose of this study was to summarize the development and validation of a scale that evaluates functional competence in three activities of daily living in adults with the disease.

Method

The study was divided into two phases: 1) scale construction/reconstruction and 2) validation of the Scale of Functional Competence in MS (SFCMS).

Phase 1: Scale Construction

In the initial stage of development, three functional mobility tasks typically encountered during daily life activities were chosen - reaching for a cup above head-height, stepping up onto a 6" step, and carrying an eight pound grocery bag a short distance. The tasks were chosen due to their routine frequency of use, involvement of both balance- and strength-related factors, and whole body rather than specific upper body movements. Each task was broken down and sequenced into steps that included both level of independence as well as movement pattern.

The scale was then reviewed by three rehabilitation professionals (two physical therapists and one occupational therapist) experienced in working with adults with neurological disorders. The functional levels within each task were randomized in order. Experts were asked to independently order the functional steps, from least to most competent, and review the scale for relevance, redundancy, and omissions. Logical validity of the scale was established through consensus of these three independent experts with steps deleted, added and/or reworded when appropriate. The revised scale was again reviewed by the team of experts for accuracy, clarity, and depth and total consensus was reached.

The scale was then evaluated using input from five ambulatory individuals with MS. Each individual was asked to identify those steps that either were irrelevant or were not feasible based upon their perceptions and disease status. No changes in the scale were made from this inquiry. A final version of the scale and associated point values for each task level are presented in Table 2.1.

Phase 2: Validation of the SFCMS

Participants

The sample consisted of ten adults with MS. Eligibility criteria for inclusion in the project included a neurologist-confirmed diagnosis of MS, the ability to ambulate without human assistance, and no severe exacerbation of symptoms requiring medical intervention for at least four months prior to the study. Participants were recruited from an on-going community-based exercise program designed for adults with MS. Participants ranged in age from 35 to 55 years ($\bar{X}$ =48.6). One participant was diagnosed with secondary progressive MS while the other nine were diagnosed with relapse-remitting MS. The ten participants in the study were mildly to moderately disabled with EDSS scores ranging from 2 to 5 on the 10-point scale. Nine of the ten participants were female.

Procedure

Upon volunteering for the study, participants were asked to read and sign an informed consent. Each then performed three trials of each of the following tasks: 1) stepping onto a 6" wooden riser, 2) reaching for a plastic cup placed on a shelf above head height, and 3) walking 12 feet straight ahead on a flat surface while carrying an eight pound grocery bag. For the stepping task, participants were instructed to step up onto the 6" wooden riser using the least amount of assistance necessary to maintain balance. They were asked to step with their preferred leg and in the same direction each trial. Prior to the reaching task, the height at which each participant could reach flat-footed and the height at which each participant could reach while raised up on the toes were determined. During each of the three reaching trials, participants stood arm's distance from the shelf unit. They were instructed to reach for the highest one of two cups set at these two predetermined heights. Participants were encouraged to reach for the highest cup they thought possible using the least amount of assistance and maintaining balance. Finally, participants were asked to walk straight ahead at a preferred and comfortable speed, while carrying the grocery bag, using the least amount of assistance needed to maintain stability. Each participant was filmed completing the tasks and video tapes were then sent to three different experts in rehabilitation management for performance ratings.

Table 2.1. Scale of Functional Competence in Multiple Sclerosis (SFCMS)

Step Up (6" height)

0 = unable to perform

1 = steps up with physical assistance of clinician, poor trunk position and inappropriate weight shift

2 = steps up with physical assistance of clinician, good trunk position and appropriate weight shift

3 = steps up with physical assistance of wall, poor trunk position and inappropriate weight shift

4 = steps up unassisted, partial trunk rotation and trunk flexion

5 = steps up with more than 1 attempt necessary and/or loses balance upon weight shifting

6 = steps up in single fluid movement with good weight shift

Reaching Object above Head Height

0 = unable to perform

1 = reaches while stabilizing on counter with 1 hand, trunk lean on support

2 = reaches while stabilizing on counter with 1 hand, widened base of support

3 = reaches while stabilizing on counter with 1 hand, natural stance

4 = reaches with partial trunk rotation and weight shift prior to reach

5 = reaches in one fluid motion, feet remain flat on floor

6 = reaches by raising up on toes, loses balance

7 = reaches in one fluid motion, raising up on toes without losing balance

Walking while Carrying Grocery Bag

0 = unable to perform

1 = walks with physical assistance (i.e. wall), poor trunk position, discontinuous steps

2 = walks with physical assistance, poor trunk position, continuous steps

3 = walks with physical assistance, good trunk position, discontinuous steps

4 = walks with physical assistance, good trunk position, continuous steps

5 = walks deviating from straight path, poor trunk position, discontinuous steps

6 = walks in straight path, poor trunk position, discontinuous steps

7 = walks in straight path, good trunk position, continuous steps

Statistical Analyses

The following psychometric analyses were used to examine the reliability and validity of the SFCMS. Two independent judges rated participants, one using the devised scale and the other ranking the participants (from most functionally independent to least functionally independent) based on professional judgment. Concurrent validity of the scale was then examined using Spearman rho coefficients of expert rankings and scored-based rankings from the scale. Reliability was evaluated by having the experts independently rate the sample of participants using the SFCMS. The same sample was again rated at a later date. Intraclass coefficients were computed to assess both interrater and intrarater reliability for each of the tasks. The average score of the three trials was used in all analyses.

Results

Correlational procedures revealed different results across the three tasks. Interrater reliability analyses revealed ratings between the two experts were highly correlated for the step task ($r = 1.0$) and reaching task ($r = .98$) and moderately correlated for the walking task ($r = .73$). Intrarater reliability was also found to be quite high with values of .97 for the stepping task, .87 for the walking task, and .86 for the reaching task.

Results of the validity analysis revealed that only the stepping task demonstrated high validity between expert rankings of functional competence and scored rankings using the instrument ($r = .94$). The task of reaching showed a slightly lower relationship ($r = .76$), while that of walking failed to demonstrate good evidence of concurrent validity ($r = .41$).

Discussion

The need to have available assessment instruments that allow for accurate evaluation of functional competence in individual tasks of daily living has been well-established (McCulloch, 1992). Moreover, the development of measures which are population-specific and include ecologically-relevant items for a particular group of individuals has also been called for (Doble, Fisk, Fisher, Ritvo, & Murray, 1994). Results of the present study suggest that the SFCMS may be a reliable and valid measure of functional competence in three specified tasks of daily living performed by adults with MS. To begin with, development of the scale ensured content validity by including input from both clinicians and individuals with MS. Reliability estimates also indicated consistency in measurement across and within raters for all three tasks.

Concurrent validity of the individual scales, however, differed. The lack of strong concurrent validity in reaching and walking tasks may have been due, in part, to the restriction in range of possible scale-based rankings compared to that of expert rankings of competence. The expert rater was better able to discriminate between participants and differentially rank them. Conversely, scale-based ratings resulted in many tied rankings. Increasing the gradation and discrimination of levels in order to better discern functional ability in individuals with MS and better operationalizing key descriptors of task levels may address this issue and remains open for future empirical study.

In general, the preliminary data suggest that the SFCMS has potential for measuring the functional competence and independence of adults with MS. The SFCMS appears to be sensitive in assessing various functional levels without compromising reliability. It is relatively easy to use and score once the tester becomes familiar with task levels and can be employed either while observing individuals directly or through later examination of video taped performances. It will be necessary to further examine the validity of this instrument by increasing the sample size upon which the scale is validated as well as by employing additional raters to more critically assess the scale's psychometric properties. The scale was found to be useful for the present sample involving individuals with higher functional levels and motivation. It will also be important to develop similar scales which further delineate assistance levels and expand upon descriptions of movement patterns for individuals with more severe deficits and somewhat lower levels of functioning.

Additionally, the scale provided a means to delineate the functional capabilities of a diverse group of individuals in three specific daily tasks. Each task was considered and scored individually rather than being added into a summed total. Such an approach may afford greater insight into specific movement capabilities and movement dysfunction as they relate to particular tasks of daily living. While the generalization of performance in these tasks to other functional skills may be limited, the scale did provide an initial attempt at discriminating among the functional capabilities of those with MS. Future efforts should be directed toward developing similar scales which include other activities of daily life important to persons with the disease.

The applicability of the SFCMS to both research and clinical practice is promising. For one, the scale may provide a reliable means by which to monitor subtle changes in functional status as a result of disease progression. The instrument also has the potential of serving as a valuable outcome measure of functional ability in specific tasks of daily living following therapeutic intervention or rehabilitative programs.

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Chapter 3

Intraindividual Variability in Constraints and Functional Competence in Individuals with Multiple Sclerosis

Susan L. Kasser

Abstract

Intraindividual variability in physical and psychological constraints was explored in five adults with multiple sclerosis ($\bar{X} = 44.2$ years). The relationship between individual constraints and functional competence in activities of daily living was also examined. Participants were assessed on muscular strength in the lower extremities, upright postural control, mood, fatigue, self-efficacy, and stress. In addition, functional competence in daily life activities was evaluated. P-technique factor analyses were performed to discover covariation patterns among variables over a four month period. Correlational procedures were then conducted to assess the relationship among the variables and functional performance. The extent of variability observed was further quantified through coefficients of variation. While the data revealed identifiable covariation patterns for four of the five participants, no commonalties in factor patterns were observed across the sample. In general, no strong relationships were found between individual variables and functional performance nor between physical and psychological variables. Results indicated that fatigue and stress fluctuated the greatest over the 16 week study for all five of the participants. Most importantly, variability in both the physical and psychological variables was shown to be much greater than that observed in performance of the functional tasks. An ecological interpretation was offered to explain the preservation of functional competence in activities of daily living in light of fluctuating constraints. Future research employing an ideographic approach to examine intraindividual variability in adults with MS may prove beneficial in affording a deeper understanding of how disease-related constraints influence functional performance. Additionally, research quantifying the extent of variability in particular constraints may afford clinicians and researchers greater insight and accuracy when assessing functional status and therapeutic outcomes in individuals with MS.

Introduction

Although there has been considerable study aimed at describing movement characteristics and differences among individuals with neurological disorders, such descriptive accounts have been insufficient in fully explaining functional changes in activities of daily living and/or social disadvantage (WHO, 1980). In an attempt to discover how deficits associated with disease impact functional ability and alter performance over time, ecological and dynamic approaches to perception and action offer considerable promise. These recent perspectives suggest that, rather than being attributed to individual impairments, actions emerge from the interaction of different systems and, in actuality, reflect the most functional movement given the prevailing capabilities of the individual and existing contextual constraints (Holt, 1993; Kugler, Kelso & Turvey, 1980). The adaptability of the system to changing constraints underscores this functional priority and is an important dimension for understanding functional competence in daily activities. How an individual's movements must change in order to adapt to changing constraints and still remain functional and why actions that still afford functional utility need not change in light of varying constraints remain open for empirical study (McGinnis & Newell, 1982; Riccio & Stoffregen, 1988).

While variability in movement is widely acknowledged, it is typically viewed from a skill or performance outcome perspective. Related to this, but much less examined, is the variability that arises from the dynamic interaction between independent factors underlying action (Newell & Corcos, 1993). In fact, there are many sources of variability that influence the product of action and the link between fluctuations in functional movements and variability of underlying systems is not yet well understood (Ivy & Corcos, 1993).

Deficits in both overall functioning and in specific systems underlying movement is a well-documented fact of multiple sclerosis (MS) (Scheinberg &

Holland, 1987). Impairments associated with the disease not only significantly influence functional independence in daily activities but also seriously impact the quality of life experienced by these individuals (Aronson, 1997). In fact, there are a number of factors that jeopardize effective performance of functional activities and impact life satisfaction. Decrements in sensory function (Nelson, Di Fabio, & Anderson, 1994; Pratt, Horak, & Herndon, 1992), strength (Dunchan, 1987), and appropriate postural responses (Panzer et al., 1991; Panzer-Decius & McFarland, 1993; Parker & Lehrich, 1990) have been reported in this population. Vercoulen and associates (1996) have suggested that significant fatigue associated with MS also seriously impacts balance and daily function. Psychological factors such as mood (Gatten, Brookings, & Bolton, 1993), self-efficacy (Schwartz, Coulthard-Morris, Zeng, & Retzlaff, 1996) and stress (Wineman, Schwetz, Goodkin, & Rudick, 1996) have also been associated with disease activity and functional independence in adults with the disease.

While variability in both overall function and in specific systems underlying movement has been duly noted in MS, it has often been considered separately. Studies helpful in enumerating the specific physiological and psychological constraints associated with the disease have been less informative regarding how such deficits interact with one another and how such factors impede effective and efficient performance of life's many tasks. While researchers have long acknowledged the multidimensional nature of MS and its impact on daily life, many are still remiss in addressing how such factors directly impact aspects of daily living other than general mobility and overall function. The relationship among the underlying factors involved in movement dysfunction as well as the association between these factors and performance in specific functional tasks in this population remain relatively unstudied to date.

Not only has documentation of neuromuscular and neuropsychological factors associated with MS been addressed as independent of one another, rarely are such changes and relationships viewed or examined within the individual over time. The study of movement dysfunction within this group has, most often, been viewed at discrete points in time rather than as a dynamic process examining how such factors relate and unfold over time. It is evident, thus far, that information pertaining directly to the variability of qualitative changes in functional outcomes and quantitative variability in constraints underlying performance is not yet available.

Notwithstanding the importance of descriptive studies identifying deficits associated with MS, the study of underlying patterns of change and relationships has much to offer to both the researcher and the clinician. An understanding of the significance of constraints, their relationship to functional performance, and the variability associated with both affords a better understanding of movement dysfunction and has important implications for interventions aimed at facilitating functional competence in adults with the disease. Assessing an individual's ability to perform functional activities and examining how performance changes over time requires appropriate research methodology. The present study examined intraindividual changes in factors related to movement dysfunction in individuals with MS and additionally delineated the association of such changes with functional competence in activities of daily living.

Method

Overview of the Design

An ideographic approach was adopted to illustrate change at the individual level. This approach entails collecting measurements from one person over an extended period of time to examine intraindividual variability and stability of the variables in question. The variables are then factor analyzed using P-technique factor analysis (Catell, Catell, & Rhymer, 1947) to provide insight into which variables covary over time. Factors, representing dimensions of time-ordered differences, reveal the pattern or structure of change for the specific individual.

In an attempt to explore the generalizability and/or uniqueness of the variability structure, several individuals can be included and concurrently assessed on similar variables over a similar time frame. By comparing factor patterns across individuals, commonalties and differences in the underlying structure of change can then be examined.

Participants

Potential participants were recruited through local and regional multiple sclerosis self-help groups and informed that participation in the study required a total of 32 sessions over a 16 week period. In order to qualify for involvement in the study, participants had to have an Expanded Disability Status Scale (EDSS) score between 2 and 5, be able to ambulate a distance of 12'-15', with or without the use of an assistive device, and not have experienced a severe exacerbation of disease-related symptoms for at least four months prior to the study. Five adults with a medical diagnosis of multiple sclerosis meeting the above-mentioned criteria and willing to commit to the extended time period volunteered to participate in the study. One of the participants was male and four were female, ranging in age from 37 to 50 years ($\bar{X}$=44.2 years).

Participant 1. This woman was 50 years old and diagnosed with secondary progressive MS at 19 years of age. She was currently on hormone replacement therapy but not taking any other prescribed medication relating to her MS. Her mobility was good as she only ambulated with a cane when walking long distances or over uneven terrain. She reported frequent swelling and numbness in her lower extremities and routine dizziness.

Participant 2. The second participant was a 41 year old woman diagnosed one year prior with relapse-remitting MS. She was on a prescribed regiment of Baclofen and/or Avonex for spasticity and typically experienced tingling in her right hand and foot. She ambulated independently with no symptoms of dizziness reported.

Participant 3. Participant 3 was a 47 year old woman with relapse-remitting MS diagnosed approximately four years earlier. She self-administered Betaseron and reported occasional numbness and some tingling in her legs and feet. She too ambulated independently with no reported dizziness.

Participant 4. This 37 year old woman was diagnosed with chronic progressive MS at age 34. The medications she was prescribed included Betaseron and Baclofen. She presented with increased symptoms of numbness and dizziness and ambulated with a cane.

Participant 5. This participant was a 46 year old man with relapse-remitting MS diagnosed at age 17. He was not currently taking any medication. Although he commonly experienced numbness and tingling in the lower extremities, blurred vision and dizziness, he ambulated independently.

Measures

Participants were assessed on 15 variables each testing day. Six of the assessments were physiological or physical in nature and included strength measurements in four muscle groups (i.e., gastrocnemius, tibialis anterior, quadriceps femoris, and hamstrings) and two assessments of balance (i.e., upright postural control and stability limits). Six other measurements were psychological in nature and involved assessment of mood (i.e., positive and negative affect), fatigue, self-efficacy to perform three functional tasks, and stress. In addition to these measurements, evaluations of functional competence in three activities of daily living were conducted.

Strength Assessment

A Kin-Com 500-H isokinetic dynamometer was used to evaluate strength of the lower extremity. This computerized device ensures that participants will be safely tested as speed is controlled and maximal effort is determined by each individual and not by an external load that must be moved. Participants warmed-up briefly with three practice trials, followed by three maximal trials at 90 degrees/second for the quadriceps femoris and hamstrings and 60 degrees/second for the tibialis anterior and gastrocnemius. Both speeds have been shown to be easily handled by individuals with MS in previous research (Kasser & McCubbin, 1996). A period of five to eight seconds was provided between each test trial to assure adequate relaxation and reduction in co-contraction following concentric muscle action. Peak force values were obtained for each trial.

Upright Postural Control

The Pro Balance Master (NeuroCom International, Inc.) with software version 5.0 was used in the study. The instrumented platform system consists of two 9" x 18" dual force plates mounted on a pair of symmetrically positioned force transducers. Vertical ground reaction forces are measured and used in calculations of center of pressure (COP) and center of gravity (COG) sway angles. During all testing on the Pro Balance Master, participants were outfitted in a harness secured to the overhead frame of the equipment to prevent the occurrence of any falls. The standardized foot position recommended by the manufacturer of the equipment was also employed for all tests conducted.

The ability of participants to maintain standing balance under various sensory conditions was assessed using the Sensory Organization Test (SOT). During the test, participants were required to maintain as steady an upright position as possible during four testing conditions: (1) eyes open, fixed surface (EO), (2) eyes closed, fixed surface (EC), (3) eyes open, sway-referenced surface (EOSR), and (4) eyes closed, sway-referenced surface (ECSR). Each testing condition lasted 20 seconds in duration and was repeated three times per session. An anterior/posterior equilibrium score (ES) was then obtained to denote sway for each trial of the four testing conditions. The equilibrium score is expressed as a percentage with greater maximum stability inferred the closer the score is to 100%.

Stability Limits

Participants were also evaluated on limits of stability using the Pro Balance Master. The Limits of Stability (LOS) test was designed to evaluate an individual's ability to volitionally move the center of mass to predetermined targets in eight different directions displayed on a video screen mounted on the equipment at eye level. Each of the targets was positioned at 100% of the individual's theoretical limits of stability, based on each participant's predicted COG height. Following an auditory and visual cue, participants were asked to lean away from their base of support as far as possible, without losing balance and/or moving their feet, in the direction of the targets. Visual biofeedback of the participant's COG was provided throughout the test. Endpoint excursion (EC), the furthest on-axis distance the COG reached by the end of the first sustained excursion toward the target was computed across all eight targets and used to represent each individual's stability limits. The score is expressed as a percentage of test target distance. Foot position was again standardized across all testing sessions.

Self-Efficacy

Participants were asked to complete a short questionnaire to provide insight into the self-efficacy, or situation-specific self-confidence, for performing specific tasks related to functional independence. The Self-Efficacy for Independent Functioning Scale (SEIFS) was specifically developed and used for this study. The scale was based upon a sound theoretical perspective (Bandura, 1977) and had been previously pilot tested using an independent sample of adults with MS. At that time, it was assessed for logical validity including whether or not tasks were typical of daily routines, wording of each item was clear, and strategies or form identified were realistic. To measure self-efficacy, participants were asked to rate on a scale of 0 to 100 (in which 0 is completely uncertain and 100 is completely certain) how confident they were in their ability to perform specific activities of daily living right at that moment.

Mood

The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) was also used in the study to assess the mood state of each participant on testing days. The PANAS consists of two 10-item self-report scales designed to measure positive affect (PA) and negative affect (NA). Responses could range from 1 (not at all) to 5 (all the time) with individuals scoring up to 50 points on either PA or NA. The instrument has demonstrated acceptable convergent validity (Bagozzi, 1993) and construct validity (Huebner & Dew, 1995).

Functional Assessment

The Scale of Functional Competence in MS (SFCMS) was used to assess the functional performance of selected activities of daily living. The scale was developed specifically for use in the study and required participants to perform three tasks for evaluation of functional competence in activities of daily living: (1) stepping up onto a 6" riser, (2) reaching for the highest of two cups placed above shoulder height, and (3) walking 12' on a flat, tiled floor while carrying an eight pound bag of groceries. Prior to any assessment of reaching, two cup heights, one that was reachable from a flat-footed position and another that was reachable while raising up on the toes, were determined for each participant. During all reaching trials, participants stood arm's distance from the shelf unit. Participants were encouraged to reach for the highest of two cups placed at the two predetermined heights while using the least amount of assistance and maintaining balance. standing arm's distance from the shelf unit. Foot position was standardized for each participant across all testing sessions for both the reaching and stepping tasks. Participants were asked to perform the task to the best of their abilities, using the least amount of assistance needed to complete the task and without losing their balance. In order to assess and score functional ability, each participant was filmed while completing the tasks. Video tapes were then reviewed and participant performance rated by a certified occupational therapist trained in rehabilitation management. The primary investigator also independently rated a random sample of participant performances for estimates of inter-rater reliability.

Pilot testing of the scale revealed high to moderate reliability and validity. The psychometric properties of the instrument were, thus, sufficient to warrant its use in the present study.

Questionnaire

Throughout the duration of the study, participants were also asked to complete a brief questionnaire involving events, amount of exercise, quality of sleep, and any changes in health either during or preceding testing days. In this way, any unusual events or circumstances that may have occurred were documented and referred to during interpretation and discussion of the data. Two important dimensions assessed on this questionnaire included perceived fatigue and perceived stress, both measured using a 5-point Likert scale (with 1 indicating relatively little and 5 indicating extreme).

Procedures

Approval to conduct the study was obtained from the Oregon State University Institutional Review Board for the Protection of Human Subjects. All participants were required to read and sign an informed consent form prior to the their involvement. Participants were asked to not change from daily routines of exercise, diet or medication during the study period unless prescribed by a physician.

Testing was conducted two times per week for 16 weeks, resulting in a total of 32 testing sessions. Each participant was assessed on consistent days of the week and at consistent times of the day throughout the four-month period. Participants completed each of the assessments with a spotter positioned nearby during all tests to insure participant safety. The first testing session was used for review of the study purpose and familiarity with each of the assessment protocols. Each test session thereafter included evaluation of standing postural control, volitional control of the COG through the limits of stability, muscular strength, functional competence in the selected activities of daily living, mood, self-efficacy, fatigue, and stress. While the psychological measures were always completed just prior to the physical assessments, all physical evaluations as well as the items or subtests within each were randomized to prevent ordering effects. Each participant was provided with frequent rests upon request to alleviate potential fatigue or risk of injury.

Data Analysis

Each participant's data was analyzed separately using the Statistical Packages for the Social Sciences (SPSS) version 6.1 (SPSS, Inc., 1994). Day one was used for familiarization with testing instruments and protocols and was eliminated from all data analyses. Data was therefore analyzed for 30 sessions. This total number of sessions was based upon a minimum of five occasions per variable needed to perform the following statistical analyses. Scores from the first trial of each evaluation were used in all statistical procedures to more closely approximate real-world conditions and negate the effects of multi-trial practice on assessment outcomes.

Since the P-technique is an approach designed to characterize change and discern patterns of covariation, only those variables that demonstrate sufficient variability are entered into the analysis. Preliminary treatment of the data entailed examining frequency distributions of measurements across the 31 sessions in order to determine if sufficient variability existed within each variable. For both strength and balance measurements, scores were rounded to whole numbers and grouped in categories using the standard error of measurement (SEM) for each measure. Self-rated assessments were left ungrouped and counted as individual values. Consistency of responses within any one variable was determined if scores for that variable fell within one response category more than 80% of test sessions or within two response categories more than 90% of the time. This stringent criteria for variable inclusion was adopted to avoid potential difficulties in factor analyzing dichotomous data (Harman, 1967; Nunnally, 1978) and has been used in prior research involving P-technique factor analysis (Hooker, 1991). Hence, those variables deemed too stable over time were dropped from the analyses. The six physical/physiological and six psychological variables included in the study were viewed as conceptually distinct domains and were, therefore, divided into two matrices and analyzed independently for each participant.

Additionally, factor scores were estimated for both the physical and psychological factors using the Bartlett method (Harman, 1967) and then correlated in order to assess the relationship between variability in the physical factors and that of the psychological factors. These factor scores were also correlated with functional performance scores to examine the relationship between competence in activities of daily living and the underlying factors. Lastly, variability in each of the physical and psychological variables was compared to variability in each functional performance through examination of coefficients of variation.

Results

The mean and standard deviation for each variable across participants are presented in Tables 3.1 through 3.6. Intraclass coefficients were also obtained to examine both intra- and interrater reliability for the functional performance measures. These correlational procedures revealed high intrarater reliability for the reaching ($r = .86$), stepping ($r = .97$), and walking ($r = .86$) tasks. Interrater reliability was also found to be quite high with coefficients of .86, .87., and .94 for the reaching, walking, and stepping tasks, respectively.

All variables related to the physical domain were retained for subsequent factor analysis for four of the five participants. Participant 3, however, did not demonstrate adequate variability in either the SOT or tibialis anterior strength measure to allow for factor analysis of the physical domain. Additionally, all three self-efficacy variables were deleted from analyses for Participant 1 and Participant 3 while the self-efficacy for reaching, self-efficacy for stepping and fatigue measures were found to be too stable and, therefore, dropped from the analysis for Participant 5. As a result of the reduced number of psychological variables remaining for these three participants, no factor analyses could be conducted for this dimension. In these cases, interclass correlations among variables, as well as with the functional scores, were examined.

All variables retained for the P-technique were intercorrelated thereby producing seven (Variable X Occasion) matrices. The seven covariance matrices were subsequently factor analyzed. Factors were extracted using the maximum likelihood method and were obliquely rotated using the direct oblimin procedure with delta set at zero (Harman, 1967). The number of factors needed to adequately

Table 3.1. Means and Standard Deviations for Strength Measurements*

Muscle Group	P1 $\bar{X}$	P1 SD	P2 $\bar{X}$	P2 SD	P3 $\bar{X}$	P3 SD	P4 $\bar{X}$	P4 SD	P5 $\bar{X}$	P5 SD
Gastrocnemius	34.0	4.5	27.3	4.8	61.0	11.0	37.3	5.2	45.6	8.6
Tibialis Anterior	15.7	2.4	17.1	1.4	8.5	1.6	18.5	2.9	24.0	1.8
Quadriceps	40.0	6.1	34.6	6.0	57.2	7.1	51.7	4.6	64.6	12.2
Hamstrings	21.4	3.3	43.1	2.5	38.5	3.9	15.2	4.3	50.4	6.4

* Expressed as pounds

Table 3.2. Means and Standard Deviations for Balance Variables*

Variable	P1 $\bar{X}$	P1 SD	P2 $\bar{X}$	P2 SD	P3 $\bar{X}$	P3 SD	P4 $\bar{X}$	P4 SD	P5 $\bar{X}$	P5 SD
SOT	78.2	2.3	89.8	2.9	87.4	8.3	81.9	4.6	82.7	3.3
LOS	75.9	6.4	78.9	7.2	90.2	4.2	71.3	4.1	62.0	4.8

* Expressed as a percentage of 100

Table 3.3. Means and Standard Deviations for Mood Variables*

	P1		P2		P3		P4		P5	
Variable	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
PA	32.9	5.8	29.4	5.0	42.2	3.3	29.9	5.9	29.7	1.9
NA	10.3	.84	12.5	2.1	10.9	1.8	12.1	2.5	11.9	2.0

* Expressed as a score out of a total of 50 points

Table 3.4. Means and Standard Deviations for Fatigue and Stress*

	P1		P2		P3		P4		P5	
Variable	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Fatigue	2.3	.75	2.2	1.1	1.6	.66	2.9	.96	2.1	.50
Stress	1.6	.86	2.4	1.3	1.7	.59	2.5	1.12	2.3	.74

* Expressed as points out of a maximum of 5

Table 3.5. Means and Standard Deviations for Self-Efficacy Scores*

	P1		P2		P3		P4		P5	
Variable	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Reach SE	98.5	1.4	83.5	11.1	98.5	5.2	77.3	15.6	96.1	1.7
Step SE	97.4	1.2	85.3	7.2	99.9	.45	73.5	14.7	96.8	1.3
Walk SE	97.6	.80	86.0	10.4	100	0.0	80.8	10.2	98.3	2.4

* Expressed as a percentage of 100

Table 3.6. Means and Standard Deviations for Functional Performance Measures*

	P1		P2		P3		P4		P5	
Variable	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Reach	6.0	.56	6.2	.78	7.0	.18	6.2	.60	6.2	.50
Step	5.1	.58	5.0	.67	6.0	.18	3.0	.00	5.3	.46
Walk	5.6	.50	5.6	.50	6.8	.50	5.4	.49	5.5	.51

* Expressed as a score out of a maximum of 7 points for Reach and Walk and a maximum of 6 for Step

describe the data was then determined. Decisions as to goodness-of-fit of each factor model was based on the following criteria: (a) the number of eigenvalues greater than one (Gutman, 1954) and (b) interpretability with respect to simple structure (Thurstone, 1947).

The results of the P-technique factor analyses are provided in Tables 3.7 through 3.10. Since the purpose of the study was to explore the extent to which variables covaried together on a day-to-day basis, the magnitude of factor loadings rather than the naming of factors was deemed more important. Analyses revealed that the factor solutions did demonstrate intraindividual variability in the physical variables for four of the five participants and in the psychological variables for two of the four participants over the 16-week period. The total variance explained by these factors for the physical domain was 71%, 62%, 40%, and 74% for participant 1, 2, 4, and 5 respectively, while the total variance explained by the psychological factors for participants 2 and 4 was 73% and 83%, respectively.

Participant 1. The result of the P-technique factor analysis for Participant 1 is provided in Table 3.7. This participant demonstrated structured variability on three dimensions over the four months. Factor I appeared to link the variability in the tibialis to that existing in the quadriceps, both muscle groups of the anterior lower extremity. Factor II seemed to reveal patterned variability between the posterior musculature of the lower extremity, namely the gastrocnemius and the hamstrings, and the quadriceps. Lastly, Factor III indicated that there existed associated variability between the LOS and SOT variables, both balance-related measures.

The extent to which these factors varied over the four month period can be seen from Figure 3.1. While no upward or downward trend can be discerned from the 16 week data, extensive day-to-day variability and some interesting peaks and dips are evident. Review of the participant's daily questionnaire, however,

Table 3.7. Factor Loadings for Participant 1

	Physical		
Variable	**I**	**II**	**III**
Tibialis	.970		
Quadriceps	.320	.311	
Gastrocnemius		.501	
Hamstring		.953	
SOT			.355
LOS			.973

Factor Correlation Matrix

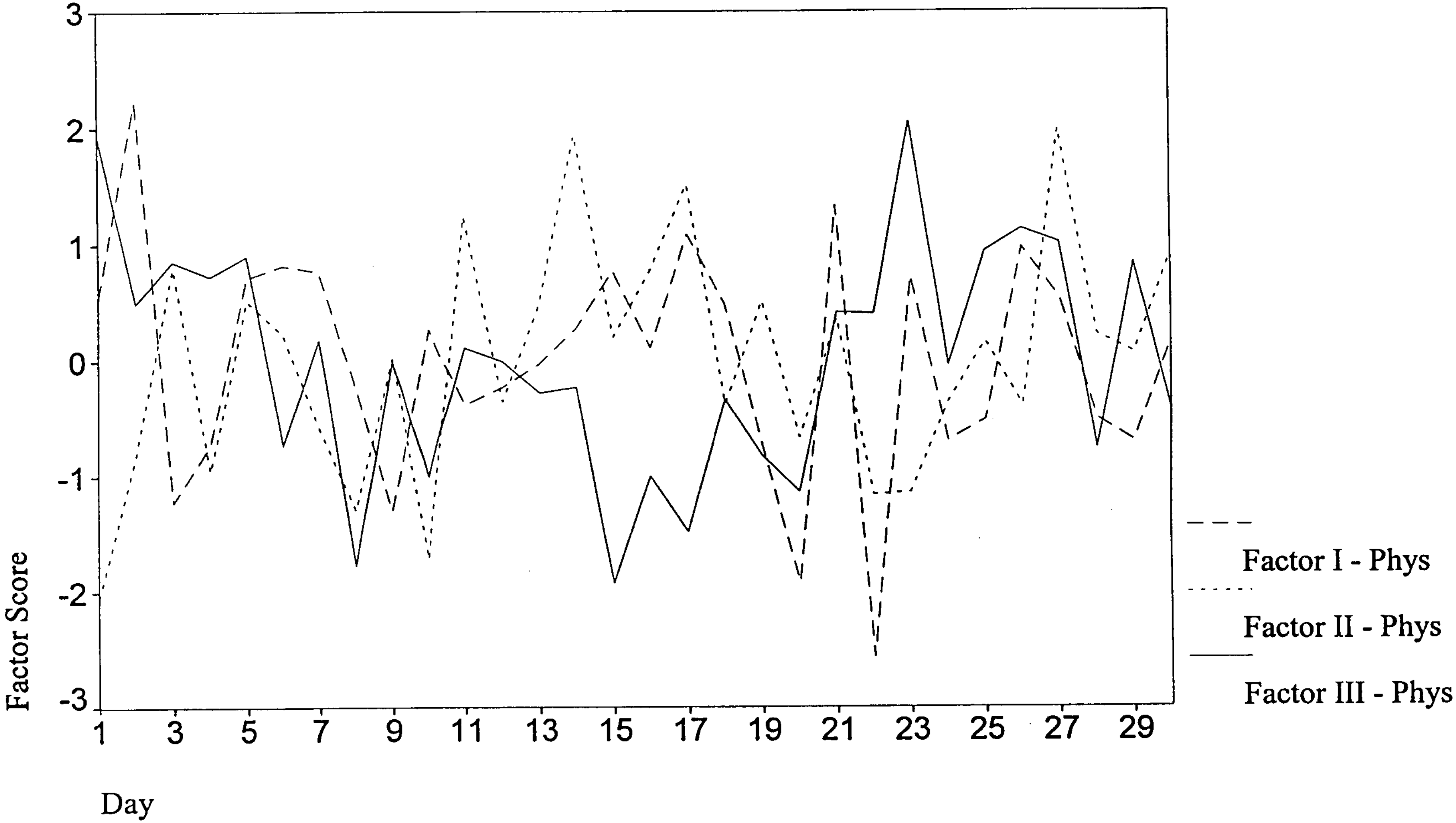
	I	II	III
I	1.00		
II	0.10	1.00	
III	0.07	-0.17	1.00

Note: Only loadings considered salient ($\geq$ 0.30) are presented.

indicated no significant events or circumstances which may have accounted for the noticeable declines in Factor III involving the balance measures across days 15 and 16. The participant was involved in a six mile fundraising walk prior to testing on day 22 that may have impacted her muscular strength on this particular day.

Due to stability of the self-efficacy variables and only three psychological variables demonstrating sufficient fluctuation, factor analysis for this domain was

Fig. 3.1. Variability in Physical Factors: Participant 1



not conducted. Examination of the correlation matrix involving these variables, the factor scores for the physical domain and the functional performance measures provided interesting information. Correlations between factor scores of the physical measures and functional tasks resulted in only one factor showing any relationship to functional performance. Factor II, posterior musculature of the lower extremity, was moderately inversely correlated with performance in the functional reaching task ($r = -.43$; $p < .01$). Neither of the other two factors demonstrated any relationship to performance in either stepping up or walking. Also of interest was the association of negative affect and stress ($r = .43$; $p < .05$) and the inverse relationship between positive affect and fatigue ($r = -.55$; $p < .001$).

The greatest variability demonstrated by Participant 1 were in the measures of stress (53.44%) and fatigue (33%). Positive affect also varied as denoted by a 17% coefficient of variation. While variability in the four muscle groups tested was found to be between 13% to 15%, variability in the two balance measures was considerably lower (3.0% for the SOT, 8.4% for the LOS). Coefficients of variation for the functional tasks revealed modest levels of variability as well, with values ranging from 9.1 %, 9.2%, and 11.5% in the walking, reaching, and stepping performances, respectively.

Participant 2. Participant 2 had both physical and psychological variables entered into separate analyses. Since a maximum likelihood extraction procedure could not be computed for this participant due to an ill-conditioned correlation matrix, the generalized least-squares method was used to extract factors for the physical variables. Table 3.8 depicts factor loadings for both physical and psychological variables. Analysis of the physical measures resulted in a two factor model. Factor I revealed that both balance measures and musculature of the ankle appeared to covary over the 16 weeks, while Factor II showed structured variability between performance on the LOS test and musculature of the knee and hip.

Table 3.8. Factor Loadings for Participant 2

	Physical	
Variable	**I**	**II**
Tibialis	-.383	
Gastroc	.691	
SOT	.986	
LOS	.403	-.363
Quadriceps		.984
Hamstring		.451

Factor Correlation Matrix

	I	II
I	1.00	
II	-0.04	1.00

	Psychological	
Variable	**I**	**II**
Positive Affect	.996	
Negative Affect	-.331	
Fatigue	-.339	-.725
Reach Self-Efficacy		.829
Step Self-Efficacy		.900
Walk Self-Efficacy		.838

Table 3.8. Factor Loadings for Participant 2 (continued)

Factor Correlation Matrix

	I	II
I	1.00	
II	0.07	1.00

Note: Only loadings considered salient (≥ 0.30) are presented.

With respect to the psychological measures, patterned variability was also represented by two factors. As depicted by loadings for Factor I, fatigue covaried with both positive and negative affect over the four months. Factor II evidenced fatigue also covarying with all three self-efficacy measures. In this case, as fatigue increased, self-efficacy to perform the three tasks decreased, and as fatigue decreased, self-efficacy increased.

Figure 3.2 and Figure 3.3 depicts the day-to-day variability in the physical as well as psychological factors, respectively. Again, day-to-day variability of the factors was apparent. The performance of Participant 2, however, seemed toa slight trend toward increased balance and ankle strength as indicated by the line representing Factor I. Factor II, self-efficacy and fatigue, also appeared to increase slightly over the four months. The low balance scores and self-efficacy levels demonstrated by this participant on day 3 may be associated with the reported fall she had the previous night. As a result, she may have been somewhat more hesitant to perform maximally on the balance tests and feel confident performing the ADL tasks. It is also of importance that no consistent pattern between medication schedule and the variability in performance was evident.

Review of the correlation matrix for factors by functional tasks indicated that none of the physical factors correlated strongly with any of the psychological

Fig. 3.2. Variability in Physical Factors: Participant 2

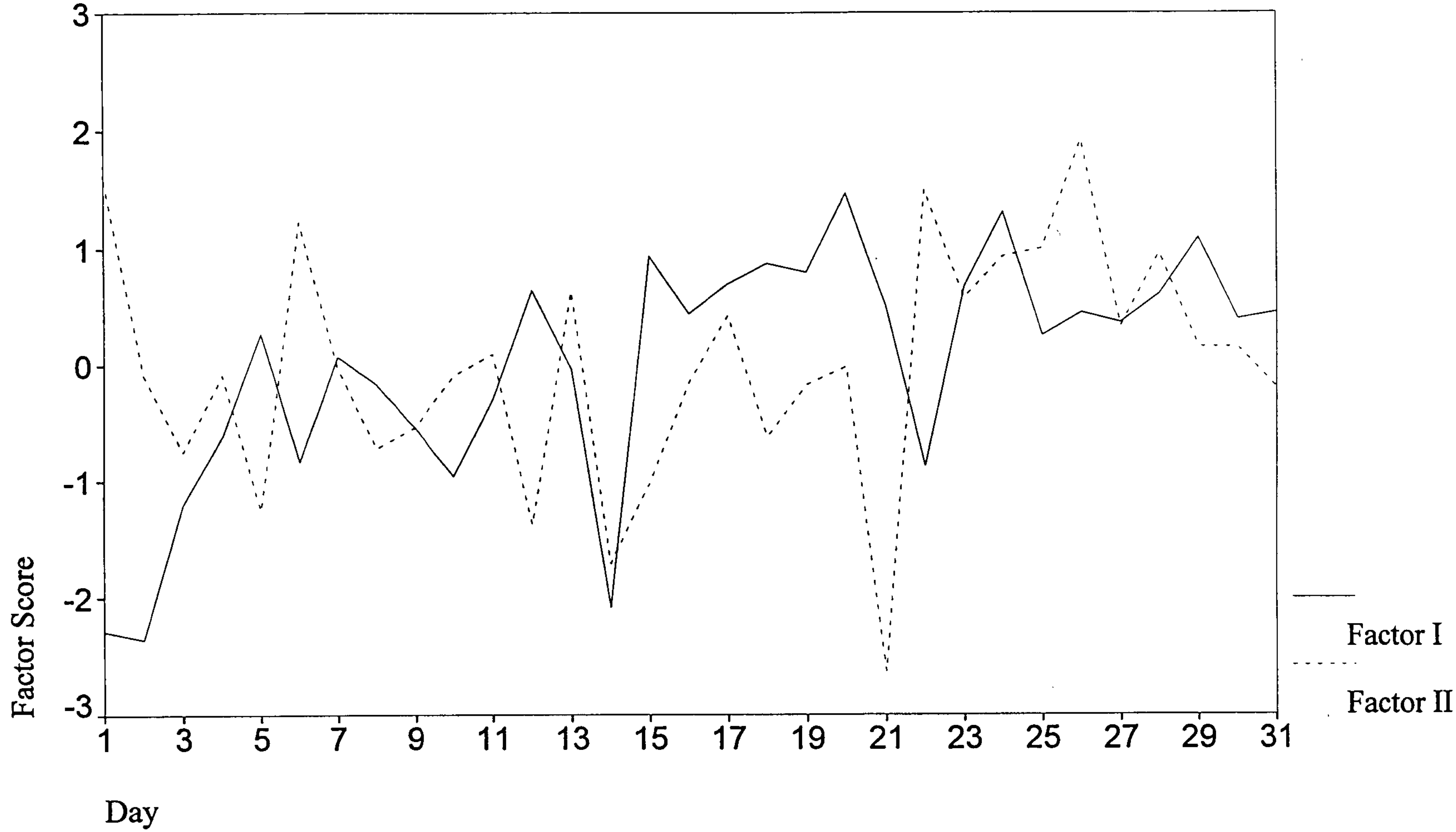
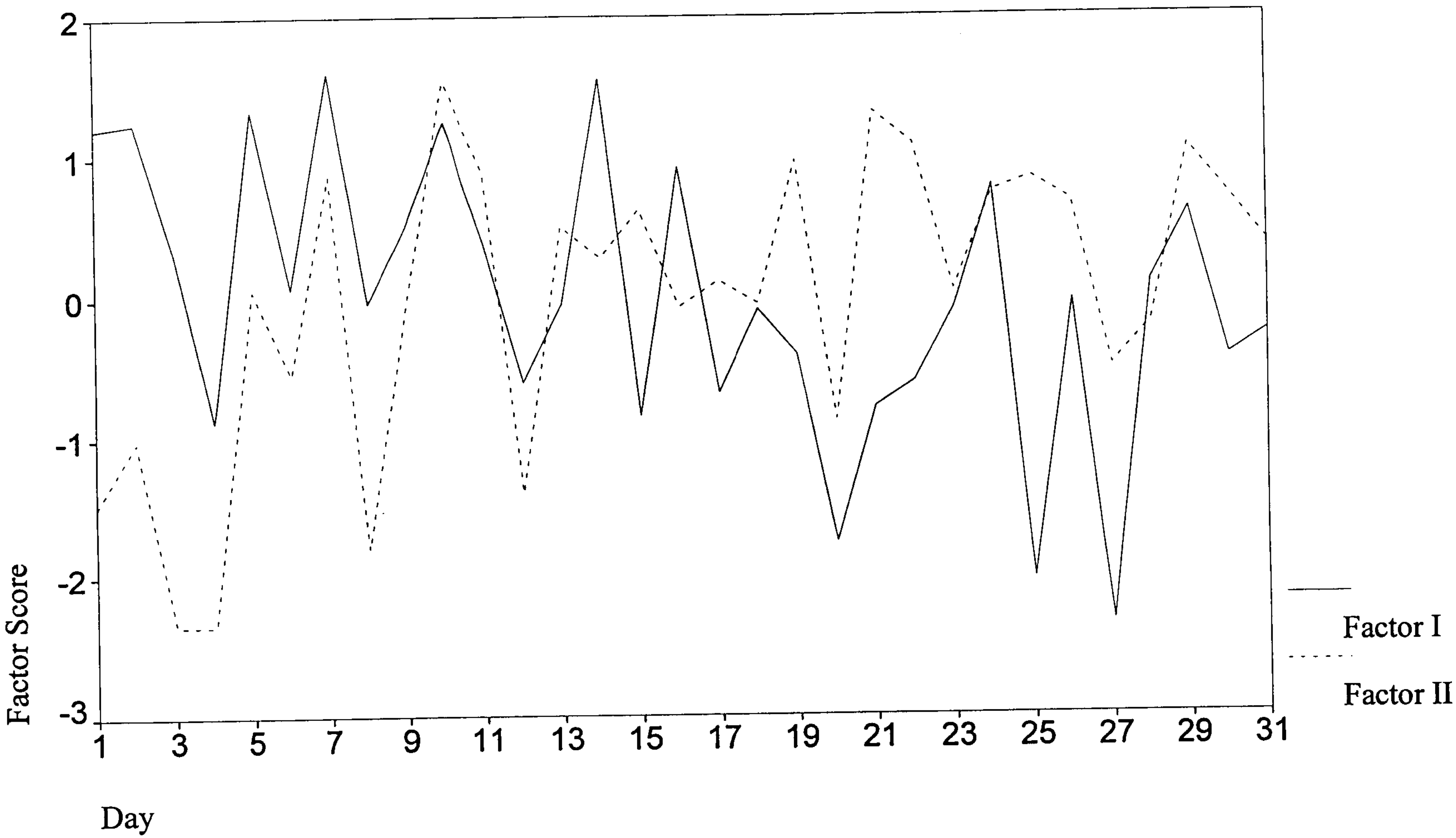


Fig. 3.3. Variability in Psychological Factors: Participant 2



factors for this particular participant. There was, however, a somewhat moderate relationship between Factor I of the physical domain and Factor II of the psychological domain ($r = .37$; $p < .05$). It appears that balance and strength of the ankle were related to this participant's fatigue and self-efficacy to perform the functional tasks. The functional task of reaching was also moderately correlated with Factor 1 of the psychological domain involving fatigue and affect ($r = .48$; $p < .01$). Of greater interest is the noticeable relationship between stress and fatigue ($r = .59$; $p < .01$) and the association of stress and the functional task of walking ($r = -.41$; $p < .05$).

As with Participant 1, Participant 2 also evidenced the greatest variability in the stress (53.2%) and fatigue (51.9%) measures. This participant, however, showed greater fluctuations in negative (17.1%) as well as positive affect (16.85%) and the three self-efficacy measures than did the first participant. Variability in the SOT was again found to be quite low (3.2%) while that in the LOS test somewhat higher (9.1%). Performance in the functional tasks varied from 9.0% in walking, to 12.6% in reaching, and 13.3% in stepping. Strength in the gastrocnemius and quadriceps varied 17.5% and 17.3% respectively, while that for the hamstrings (7.5%) and tibialis anterior (8.1%) were much lower.

Participant 3. Since no factor analysis could be conducted on either the physical or psychological measures, a correlation matrix was examined to discern relationships among the variables in question. Findings revealed a moderate inverse association between fatigue and positive affect ($r = -.58$; $p < .01$) as well as a moderate relationship between stress and negative affect ($r = .50$; $p < .01$). Performance in the functional stepping task was found to be strongly related to negative affect ($r = -.85$; $p < .001$) and to a lesser extent stress ($r = -.41$; $p < .05$). No other noteworthy correlations were found between the other variables in question.

Coefficients of variation also revealed that, for this participant, very little variability in performance of the functional tasks nor self-efficacy existed. Her fatigue (40.2%) and stress levels (34.4%), however, varied greatly over the course of the 16 weeks. This participant did show some variability in the strength of her tibialis anterior (19.1%) and gastrocnemius (18.0%) as well as some in the SOT measure (9.5%).

Participant 4. The factor pattern for both physical and psychological variables is shown in Table 3.9. For the physical dimension, Factor I included musculature of the posterior lower extremity, tibialis, and SOT. No other factor had more than one variable load on it. It appears that as strength in the muscle groups associated with the ankle and posterior aspect of the thigh varied so too did performance on the SOT measure.

The factor pattern for the psychological variables was much less clear as to its underlying pattern. Findings did not seem to reveal any structured variability or meaningful covariation among the variables. Instead, the variability associated with each of the measures appeared to be more random and unrelated.

Nevertheless, variability in both the physical factor and the psychological factors over the 16-week study can be observed from Figure 3.4 and Figure 3.5 respectively. While the underlying pattern may be difficult to discern, the variability of the variables assessed is quite obvious. Moreover, the variability appears to be somewhat more subtle and not as dramatic as it seemed for Participant 2. And as with the previous participant, there was evident a slight upward trend in the three factors. A change in medication and the subsequent physical aftermath of weakness and shakiness may account for the noticeable change in scores on day 21. No other association of medications and variability were observed.

Comparisons between the factor scores of both domains and performance scores in the functional tasks showed no relationships of any importance other than

Table 3.9. Factor Loadings for Participant 4

Variable	Physical I
Tibialis	.819
Gastroc	.569
Quadriceps	
Hamstring	.745
SOT	.558
LOS	

Variable	Psychological I	II
Positive Affect		-.822
Negative Affect	-.532	.907
Reach Self-Efficacy	.876	-.313
Step Self-Efficacy	.999	-.319
Walk Self-Efficacy	.586	-.579
Fatigue	-.465	.829

Factor Correlation Matrix

	I	II
I	1.00	
II	-0.35	1.00

Note: Only loadings considered salient ($\geq$ 0.30) are presented.

Fig. 3.4. Variability in Physical Factor: Participant 4

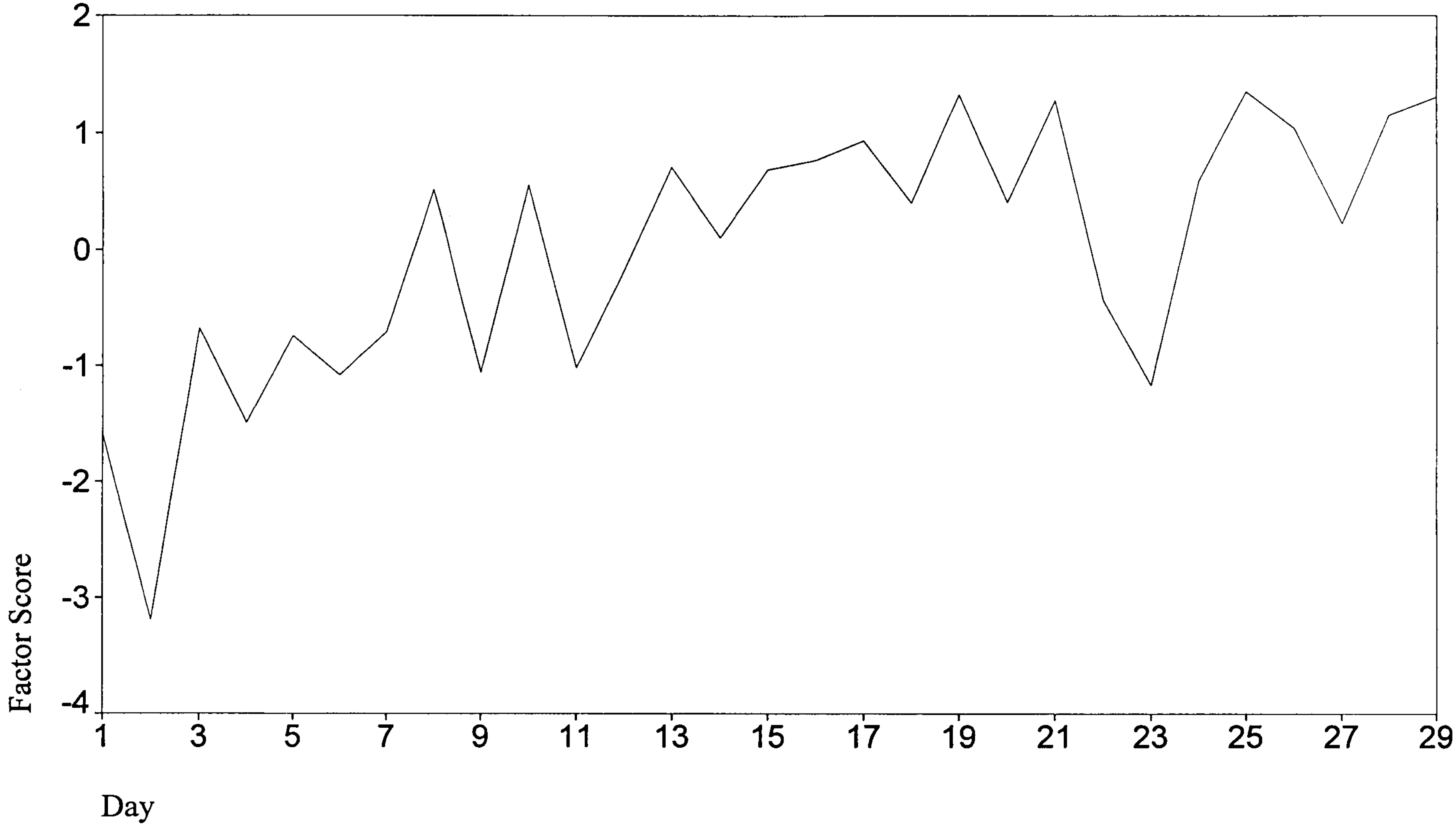
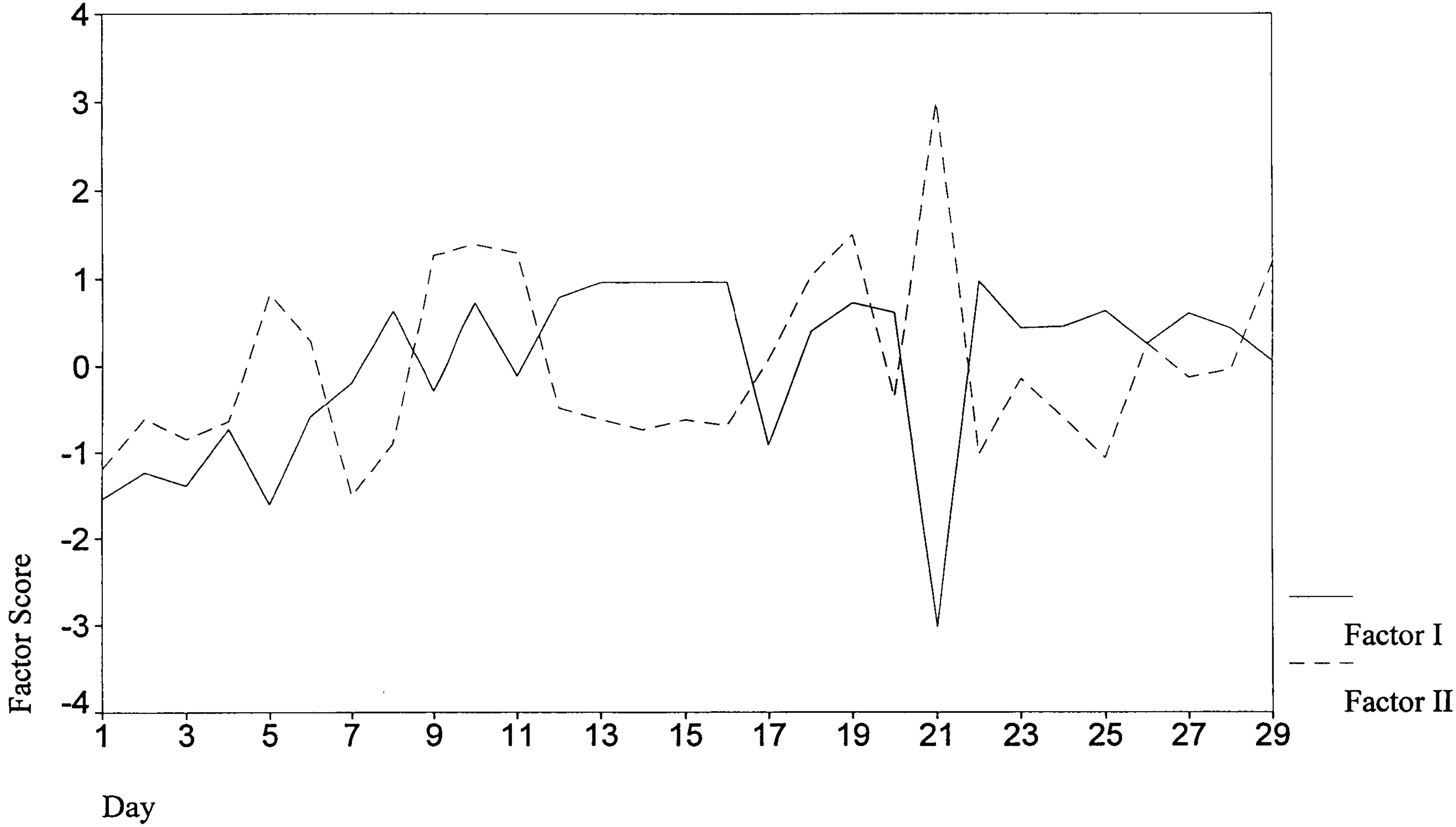


Fig. 3.5. Variability in Psychological Factors: Participant 4



between stress and walking ($r = .40$; $p < .05$). Independent correlations between the psychological variables, however, revealed a strong relationship between fatigue and negative affect ($r = .81$; $p < .001$), fatigue and positive affect ($r = -.62$; $p < .01$) and a moderate correlation between stress and negative affect ($r = .42$; $p < .05$).

Participant 4 evidenced the greatest variability in her self-efficacy to perform the tasks of daily living (e.g., 20.0 %) as well as in her muscular strength (e.g., hamstring 28.6%) as compared to the other participants in the study. As with the others, though, she too varied greatly in her fatigue (32.8%) and stress level (44.6%). In comparison to the extent of variability in her strength, this participant demonstrated relatively lower variability in her functional performance, ranging from 0% for stepping and 9% for reaching and walking.

Participant 5. Factor loadings for the physical domain are presented in Table 3.10. Factor I included the LOS variable as well as the musculature of the knee/hip and posterior ankle. Factor II involved the same musculature but with the SOT measure instead, indicating that the variability in the musculature associated with the SOT test was also associated with performance on the LOS test. While this factor pattern is somewhat difficult to interpret, Factor I and Factor II were in fact moderately correlated ($r = -.56$) indicating that the covariation among variables was associated across both factors.

Figure 3.6 depicts the day-to-day variability in the physical factors for Participant 5. While there are some obvious points of extreme fluctuations, the variability was, for the most part, much less in magnitude across many of the days. In fact, the two points at which the lowest performance scores were observed (i.e., day 7 and 20) were just after two days in which this individual played golf and worked on some major remodeling jobs around his home. The muscular and mental fatigue resulting from such laborious events and the lack of sufficient time to physically recuperate may have impacted performance the following days. As with some of the other participants, a slight increase in the physical measures were also observed for this participant by the end of the study period.

A factor analysis of the psychological domain was not possible due to the consistency of variables. Of particular interest, though, were the moderate relationships between stress and fatigue (.62, p<.001), stress and negative affect (.52, p<.01), and fatigue and negative affect (.59, p<.01).

Table 3.10. Factor Loadings for Participant 5

	Physical	
Variable	**I**	**II**
LOS	.380	
Gastroc	.564	-.445
Quadriceps	.559	-.999
Hamstring	.998	-.520
SOT		-.435
Tibialis		

Factor Correlation Matrix

	I	II
I	1.00	
II	-0.56	1.00

Note: Only loadings considered salient ($\geq$ 0.30) are presented.

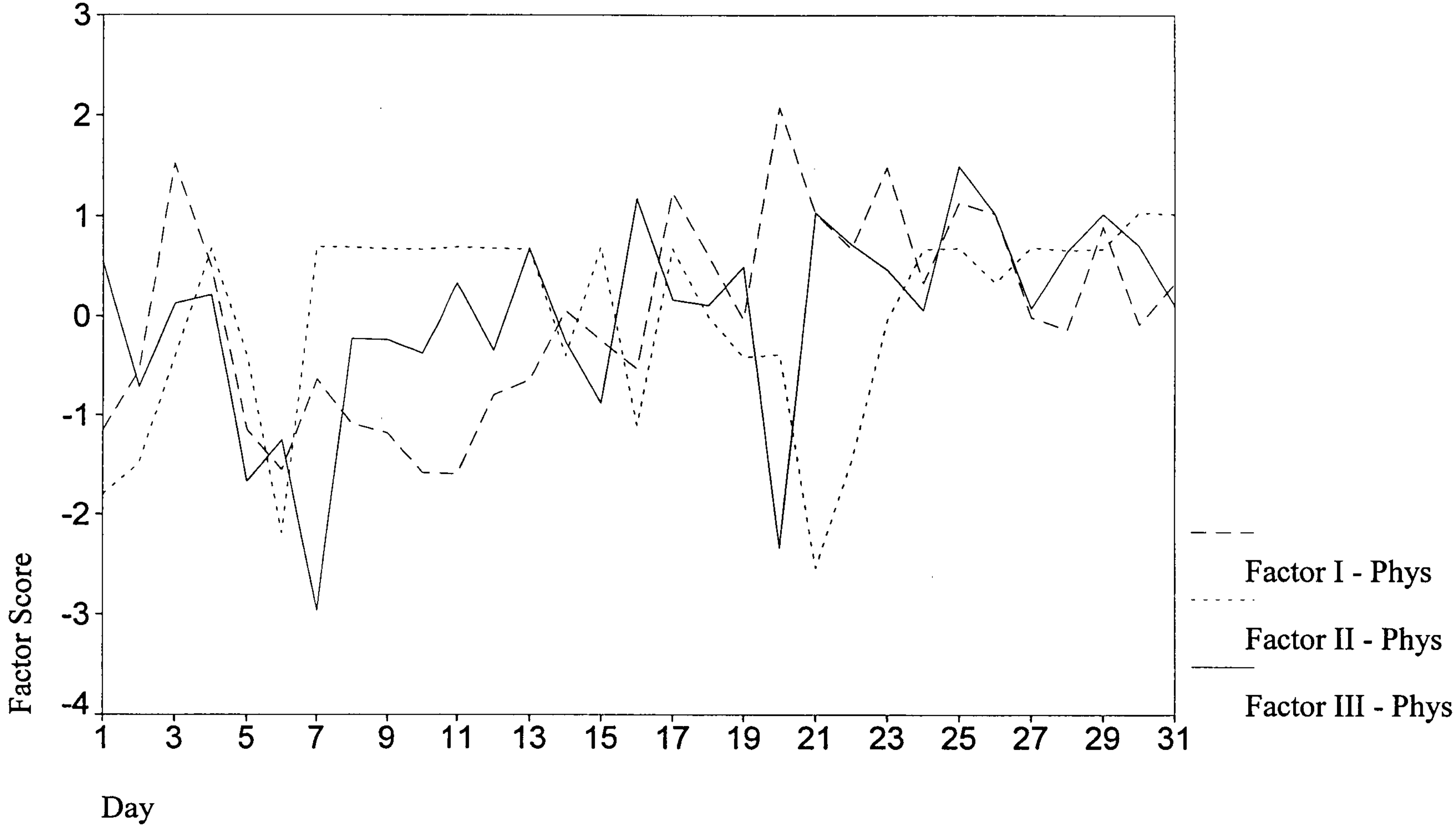
As with Participant 3, Participant 5 showed virtually no variability in his self-efficacy to perform the functional tasks and relatively little variability in the two balance measures. Unlike the previous participant, however, he did fluctuate more in both his performance of those tasks (approximately 7.0 to 9.0% across the three tasks) as well as the strength measurements ascertained. His gastrocnemius and quadriceps strength varied about 18.0% while that of his hamstrings varied 12.0% and tibialis anterior 7.5%. As with all the others, this participant too demonstrated the greatest variability in stress (32.3%) and fatigue (23.4%).

Discussion

The focus of the study was to examine intraindividual variability in the underlying constraints associated with MS and assess the relationship between these fluctuating constraints and performance in functional tasks of daily living. Empirical efforts aimed at further understanding the disease have typically focused on the magnitude of specific deficits or how often these constraints potentially varied. No empirical research to date has attempted to quantify variability in underlying constraints on function nor describe the pattern of change in these constraints. Moreover, the relationship between physical and psychological constraints and function has not been systematically explored. Specifically, a P-technique factor analysis was used to describe the data. Such a measurement technique describes change at the individual level and affords insight into the patterns of change by yielding information about which variables covary together over time (Nesselroade & Ford, 1985).

The variability in strength and balance shown within participants involved in this study was consistent with that reported in the literature regarding MS (Chan, Hugos, Morrison, & Theriot, 1994; Herrera, 1990). Fluctuations demonstrated in the psychological variables of mood, stress and fatigue were also supportive of the literature base surrounding this population (Gatten et al., 1993; Zeldow & Pavlou,

Fig. 3.6. Variability in Physical Factors: Participant 5



1984). Quantification of this variability within an individual over time, however, remained empirically undocumented until this point.

The most interesting aspect of the data involved observations between fluctuations in individual constraints and competency in functional performance. In general, variability in the underlying constraints was larger, and in some cases much larger, than variability in performance of the ADL tasks. For instance, variability in strength of the quadriceps ranged from 13% to 28% across the five participants, while concurrent fluctuations in performance of the stepping task varied from 0% to 13% for these same individuals. Given the constancy of both context and task goals, the relatively greater variability identified in the individual constraints and reduced variability in performance appears to support the functional priority of the system (Riccio, 1993). From a more dynamic perspective, movements used to perform functional tasks may have reflected the tendency of the system to organize and optimize movement given existing constraints (Kugler, Kelso, & Turvey, 1980). In the present study, greater consistency in performance and preservation of a functional outcome were evident in light of the prevailing and dynamically changing constraints. While slight variability in the movements used to perform the functional tasks was found, deficits were not a level sufficient enough nor variable enough as to result in a new movement. Movement responses remained functional and stable, requiring greater changes in the magnitude of fluctuations if performance was to vary. Other more challenging tasks or these same tasks performed in real-world settings may have been more reactive to fluctuating constraints and perhaps would have varied considerably. While the generalization of findings regarding these tasks to other functional skills is limited, the study did provide an initial attempt at examining the relationship between variability in underlying constraints and variability in functional capabilities of those with MS. Future research involving other tasks of daily living appears necessary to further study the relationship of underlying constraints and functional performance and more deeply understand this adaptability issue.

Another key finding of the study was the greater variability demonstrated in the psychological variables as compared to the physical variables. Participants fluctuated significantly in both fatigue and stress over the four month period. Interestingly enough, no significant relationship was found between these two psychological constraints and any of the physical ones. For instance, extent of fatigue was not at all associated with levels of strength. It appears that participants' perceptions of being fatigued were more general in nature than specifically related to musculoskeletal function. Unlike these two aspects, self-efficacy to perform the functional tasks remained quite high and relatively stable for the majority of participants. The functional tasks were not deemed very difficult regardless of fluctuations in physical constraints and perceptions of fatigue and stress. The correlations depicting the relationship between self-efficacy and functional performance may have been attenuated due to this lack of variability demonstrated in each of the self-efficacy and performance measures. The question as to whether or not greater fluctuation in self-efficacy, and a stronger relationship between self-efficacy and performance, had the tasks been more different or measured in real-world and dynamically changing environments remains unanswered and open for future study.

The variability in terms of the magnitude and timing of fluctuations across individuals with MS has previously been documented. Based upon this preliminary study, it appears now too that the underlying structure of this variability varies across those with the disease. While the study attempted to find commonalties in the underlying structure of change across participants, none were found. The unique patterns of variability observed in participants may, in part, be attributed to the heterogeneity of the sample. Participants involved in the study were diagnosed with different types of MS. Moreover, constraints other than those measured may have been involved in the underlying variability and could have had a significant impact on functional performance. Future investigations involving a more homogeneous sample and including other constraints associated with the disease may evidence greater similarity in the variability patterns.

Findings from the present study revealed the magnitude of short-term variability in many of the constraints associated with MS. While variability is often used to characterize group differences in movement skills, whether there are clearly distinct differences between individuals with MS and other populations on the different variability dimensions is open for question. Furthermore, this variability must not only be acknowledged in empirical efforts, but also considered in clinical practice aimed at examining rehabilitation outcomes. Since traditional practice in exercise-related programs for persons with MS typically employs single measurement data by which to assess the functional status of individuals and/or the efficacy of therapeutic endeavors, caution must be exercised with respect to the accuracy of subsequent interpretations. Such techniques and designs render decisions as to what were true results of the intervention and what were artifacts of the inherent variability and timing of measurements debatable. Until the magnitude and extent of variability can be determined prior to therapeutic treatment and measurement strategies change to incorporate multiple testing sessions, conclusions as to the efficacy of specific interventions are tenuous.

The documented variability of multiple constraints associated with MS and the association of these constraints to functional competence were important aspects of this study. While the single subject design and analyses of the data may be questioned with regard to its generalizability, this methodological approach provided the means to examine and quantify short-term intraindividual variability in persons with the disease. It is hoped that such an approach will stimulate further study emphasizing the individual and employing appropriate research techniques by which to assess change. Future empirical research should attempt to include additional subjects and examine individuals over longer periods of time to capture extreme fluctuations surrounding periods of relapse and remission and shed more light on the impact of such variability on function. Only by virtue of such information can practitioners and clinicians hope to develop and accurately assess treatment programs efficacious in promoting maintenance of functional competence and quality of life for persons with MS.

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CONCLUSION

Adults with MS are often faced with considerable problems ranging from a difficulty performing once easily mastered daily life tasks to an inability to engage in previously enjoyed recreational and social pursuits. While it is widely recognized that many physical and psychological constraints associated with MS interact to impact these daily functions and endeavors, much of the past research has focused on identifying and documenting individual deficits. Rarely has the relationship among constraints underlying movement been empirically examined. This is most likely centered around the fact that MS is a highly complex disease involving many bodily systems and functions. While it may be impractical to include all of the possible constraints associated with the disease in a single study, MS research often neglects to consider the multifaceted nature of movement and dynamic interaction of constraints in the study design. Research directed toward examining the interplay between constraints is an important step in fully understanding the nature of the disease and similarities and differences across those with the condition.

Employing longitudinal research designs may also provide some insight into potential directions for intervention research. By evidencing associations between constraints, subsequent studies can be designed to reveal causal relationships. For instance, findings of the present study revealed a significant association between mood and fatigue. This information may be useful in designing intervention studies to examine whether or not mood enhancing strategies could beneficially decrease perceptions of fatigue and positively impact quality of life. Observed relationships between other constraints may offer similar possibilities for intervention research.

The observation that underlying constraints may vary much more significantly than does functional performance also offers a foundation for future study. Research aimed at identifying the physical and/or psychological variables that influence or constrain the movement patterns used for a particular task and individual is needed. Further study can then attempt to discover whether specific constraints can be targeted through intervention to bring about a more optimal functional outcome. Adopting a theoretical approach offers a principled way to explore these empirical directions and more fully understand the impact of MS on daily life.

One problem that hinders accurate and ecologically meaningful assessment of function is inconsistency in definitions of functional competence and a lack of appropriate assessment tools. Further, the value placed on independent performance of functional skills varies dependent upon both the individual and the task. In some situations, use of physical assistance may be preferable to independence depending upon whether the individual strives to save time, conserve energy , or reduce psychological stress (McCulloch. 1992). Functional measures which offer clear definitions of functional levels and movement patterns as well as consider individual priority are needed. By understanding what constitutes movement quality and considering the relevancy of particular daily tasks over others, the optimal means by which to improve ADL performance may be better realized.

Finally, it is important to conduct research which has direct clinical significance. Studies employing group designs provide relatively little practical information for clinicians attempting to facilitate the functional capabilities of individuals with MS. Future research which emphasizes a single-subject approach and employs appropriate analysis techniques will undoubtedly offer clinicians information that is more meaningful and can be readily used in practice.

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APPENDICES

APPENDIX A

INFORMED CONSENT

TITLE: CONSTRAINTS ON FUNCTIONAL CAPABILITIES IN PERSONS WITH MULTIPLE SCLEROSIS

Principle Investigators: Dr. Jeff McCubbin (Susan L. Kasser)

1. I have been informed that the purpose of the study is to examine variability in strength, balance, self-confidence, and mood over a four-month period and how such changes relate to performance of activities of daily living in adults with MS.

2. I am aware that I will be participating in the project two times per week for a period of 16 weeks. Each session will last approximately 60 to 75 minutes and consist of various assessments related to balance and functional abilities. Each session, I will be tested on the strength of my lower limbs, standing balance, mood, self-confidence, and the ability to reach, step up, and walk. I will also be asked to complete a brief questionnaire describing my fatigue, stress and exercise levels as well as any changes in physical condition or well-being. My first two sessions at the Motor Behavior Laboratory of Oregon State University will familiarize me with the both the testing equipment and assessment procedures used in the study.

3. I understand that the results of this study may not have direct benefit to me as a participant but will contribute to the general understanding of balance control and specific development of therapeutic programs aimed at improving balance difficulties in those with MS. As a potential benefit of participating in the study, I will, however, be provided with comprehensive information of my balance and strength and will receive an individualized rehabilitative assessment of my functional capabilities from a certified occupational therapist upon completion of the study. This information, while providing me insight, may or may not be helpful in improving my balance and functional capabilities.

4. I am also aware that potential risks to participants in this study are minimal. Possible discomforts include initial muscle soreness and a slight increase in fatigue. However, frequent rests will be provided and muscle soreness should subside by the second week of testing. I further understand that I will be wearing an overhead harness designed to prevent me from falling during all balance testing.

5. I realize that the results of the investigation may be published but that my name will not be revealed. The information obtained during this study will be treated as confidential with my right to privacy assured. All data will be analyzed and referred to with a subject code number which will be known only to the principle investigators and stored securely throughout the course of the study.

6. I understand that the University does not provide a research subject with compensation or medical treatment in the event I am injured as a result of participation in the study.

7. Questions concerning my rights as a subject in this research can be directed to the Institutional Review Board for the Protection of Human Subjects at the Research Office of Oregon State University.

8. I have read the above information. The nature, procedures, demands, risks and benefits of the project have been explained to me and I have been given the opportunity to ask questions concerning any aspect of the study. I understand that my participation is strictly voluntary and that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. Any questions concerning the research or my involvement should be directed to Dr. Jeff McCubbin at 737-5921 or Susan Kasser at 737-3402.

9. I will receive a copy of this form for my records.

Subject Signature ______________________________ Date ____________

Address

____

____

Telephone ____________________________________

Investigator Signature ______________________________ Date _________

APPENDIX B

SELF-EFFICACY FOR INDEPENDENT FUNCTIONING SCALE (SEIFS)

Reaching

At this moment, how certain are you that you can:

1. Reach for a cup on a shelf above your head by leaning against the wall or counter and holding onto the counter without losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

2. Reach for a cup on a shelf above your head by holding onto the counter or wall without losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

3. Reach for a cup on a shelf above your head unassisted without getting up on your toes and not losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

4. Reach for a cup on a shelf above your head unassisted and up on your toes without losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

Stepping

At this moment, how certain are you that you can:

1. Step up onto a 6" step with the assistance of a clinician and without losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

2. Step up onto a 6" step while using the wall to maintain your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

3. Step up onto a 6" step unassisted but by rocking heel-to-toe prior to stepping and not losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

4. Step up onto a 6" step unassisted and in a single fluid motion without losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

Walking

At this moment, how certain are you that you can:

1. Walk 12' with physical assistance of clinician while carrying a 8 lb. grocery bag and not losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

2. Walk 12' using the wall for support while carrying a 8 lb. grocery bag and not losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

3. Walk 12' unassisted but not in a straight path while carrying a 8# grocery bag and not losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

4. Walk 12' unassisted in a straight path while carrying a 8# grocery bag and not losing your balance?

0 10 20 30 40 50 60 70 80 90 100
completely uncertain moderately certain very certain

APPENDIX C

The PANAS

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way right now. Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

_____ interested	_____ irritable
_____ distressed	_____ alert
_____ excited	_____ ashamed
_____ upset	_____ inspired
_____ strong	_____ nervous
_____ guilty	_____ determined
_____ scared	_____ attentive
_____ hostile	_____ jittery
_____ enthusiastic	_____ active
_____ proud	_____ afraid

APPENDIX D

PARTICIPANT QUESTIONNAIRE

1. How much stress (because of hassles, demands, etc.) were you under today?

1 relatively little	2	3	4	5 extreme stress

2. Please note whether you exercised at some point during the day.

3. Write down any illness or physical condition that may have affected you today (cold, flu, menstrual period).

4. List any important things that were on your mind today (worries, dreams, events, etc.).

5. Rate the extent you feel fatigued right at this moment.

1 very slightly/ not at all fatigued	2 a little	3 moderately	4 quite a bit	5 extremely fatigued

6. Please describe how much sleep you had last night and how well you slept.

APPENDIX E

CORRELATION MATRICES

Correlation Matrix for Participant 1

	FUNCR	FUNCS	FUNCW	GASTR	TIB	QUAD	HAMS	SOT	LOS	PA
FUNCR	1.00									
FUNCS	-0.00	1.00								
FUNCW	0.05	-0.02	1.00							
GASTR	-0.00	0.31	-0.15	1.00						
TIB	0.27	-0.04	0.11	-0.02	1.00					
QUAD	-0.25	-0.04	0.03	0.13	0.25	1.00				
HAMS	-0.46	0.23	-0.27	0.44	-0.37	0.22	1.00			
SOT	-0.16	0.17	0.03	0.00	0.20	-0.07	-0.00	1.00		
LOS	-0.09	-0.05	0.21	-0.27	0.03	-0.14	-0.11	0.31	1.00	
PA	-0.22	-0.28	-0.08	-0.13	-0.00	0.24	0.15	0.22	0.12	1.00
NA	-0.10	0.02	0.03	-0.17	-0.24	0.04	0.04	-0.06	-0.09	-0.17
SER	0.07	0.34	0.15	0.04	-0.21	0.10	0.28	-0.11	-0.14	0.29
SES	0.00	0.13	0.08	0.07	-0.06	0.09	0.06	0.40	0.07	0.28
SEW	-0.39	-0.01	-0.12	-0.04	-0.06	0.05	0.41	0.18	0.08	0.45
FATIG	0.23	-0.07	0.06	-0.17	-0.17	-0.21	-0.31	-0.33	-0.02	-0.56
STRESS	0.25	-0.22	0.30	-0.28	-0.14	-0.04	-0.24	-0.02	0.42	-0.03

Correlation Matrix for Participant 1 (continued)

	NA	SER	SES	SEW	FATIG	STRESS
NA	1.00					
SER	0.07	1.00				
SES	-0.14	0.30	1.00			
SEW	-0.04	0.11	0.00	1.00		
FATIG	0.12	-0.36	-0.36	-0.33	1.00	
STRESS	0.38	0.13	0.05	-0.08	0.26	1.00

Correlation Matrix for Participant 2

	FUNCR	FUNCS	FUNCW	GASTR	TIB	QUAD	HAMS	SOT	LOS	PA
FUNCR	1.00									
FUNCS	0.12	1.00								
FUNCW	0.00	-0.06	1.00							
GASTR	-0.05	0.36	0.20	1.00						
TIB	0.04	-0.05	-0.04	-0.17	1.00					
QUAD	0.49	0.18	-0.05	-0.07	0.13	1.00				
HAMS	0.20	0.11	-0.08	0.26	-0.07	0.40	1.00			
SOT	-0.18	0.21	-0.01	0.69	-0.37	-0.05	0.29	1.00		
LOS	-0.56	-0.00	-0.27	0.14	-0.08	-0.43	-0.08	0.34	1.00	
PA	-0.10	-0.19	0.02	-0.32	0.40	0.00	-0.17	-0.51	-0.09	1.00
NA	0.20	0.04	-0.07	-0.07	-0.10	0.21	0.19	0.05	-0.27	-0.33
SER	-0.23	0.13	0.08	0.52	-0.27	-0.06	0.24	0.42	0.31	-0.14
SES	-0.17	0.13	-0.12	0.40	-0.22	0.04	0.48	0.35	0.37	-0.14
SEW	-0.30	0.22	-0.14	0.29	-0.48	0.00	0.36	0.29	0.27	0.01
FATIG	0.23	-0.10	-0.09	-0.11	-0.09	-0.01	-0.44	-0.07	-0.05	-0.28
STRESS	0.28	-0.14	-0.44	-0.42	-0.14	0.20	-0.23	-0.28	0.00	0.06

Correlation Matrix for Participant 2 (continued)

	NA	SER	SES	SEW	FATIG	STRESS
NA	1.00					
SER	0.00	1.00				
SES	-0.06	0.75	1.00			
SEW	0.02	0.71	0.75	1.00		
FATIG	0.02	-0.57	-0.63	-0.59	1.00	
STRESS	0.24	-0.36	-0.26	-0.09	0.51	1.00

Correlation Matrix for Participant 3

	FUNCR	FUNCS	FUNCW	GASTR	TIB	QUAD	HAMS	SOT	LOS	PA
FUNCR	1.00									
FUNCS	-0.03	1.00								
FUNCW	-0.08	0.29	1.00							
GASTR	0.15	0.50	0.30	1.00						
TIB	0.00	0.38	0.25	0.33	1.00					
QUAD	0.34	0.20	0.28	0.31	-0.25	1.00				
HAMS	-0.06	-0.04	-0.08	0.05	-0.09	0.46	1.00			
SOT	-0.04	-0.08	-0.00	0.03	-0.62	0.63	0.31	1.00		
LOS	-0.22	0.02	-0.10	-0.00	0.00	0.19	0.42	0.40	1.00	
PA	0.13	-0.10	-0.15	0.24	0.11	-0.12	-0.33	-0.10	-0.03	1.00
NA	-0.01	-0.85	-0.22	-0.59	-0.45	-0.19	-0.02	0.05	-0.13	-0.06
SER	0.30	-0.05	-0.13	0.04	-0.20	0.36	0.21	0.13	-0.03	0.15
SES	-0.03	-0.03	-0.08	0.07	-0.57	-0.56	0.27	0.95	0.39	-0.10
SEW	*	*	*	*	*	*	*	*	*	*
FATIG	-0.10	-0.10	-0.25	-0.44	-0.31	-0.00	0.18	0.16	0.25	-0.58
STRESS	0.22	-0.41	-0.23	-0.18	-0.09	-0.38	-0.28	-0.40	-0.33	-0.02

* Unable to calculate coefficient due to lack of variability in SEW

Correlation Matrix for Participant 3 (continued)

	NA	SER	SES	SEW	FATIG	STRESS
NA	1.00					
SER	0.10	1.00				
SES	-0.01	0.04	1.00			
SEW	*	*	*	1.00		
FATIGUE	0.30	-0.13	0.18	*	1.00	
STRESS	0.50	-0.00	-0.41	*	0.07	1.00

* Unable to calculate coefficient due to lack of variability in SEW

Correlation Matrix for Participant 4

	FUNCR	FUNCS	FUNCW	GASTR	TIB	QUAD	HAMS	SOT	LOS	PA
FUNCR	1.00									
FUNCS	*	1.00								
FUNCW	-0.11	*	1.00							
GASTR	0.05	*	-0.25	1.00						
TIB	0.02	*	-0.09	0.46	1.00					
QUAD	-0.03	*	-0.13	0.11	0.09	1.00				
HAMS	0.09	*	-0.15	0.42	0.62	0.18	1.00			
SOT	0.05	*	-0.27	0.32	0.47	0.20	0.40	1.00		
LOS	0.26	*	0.02	0.13	0.09	0.07	0.00	0.01	1.00	
PA	0.36	*	0.05	-0.18	-0.39	-0.19	-0.21	-0.39	0.24	1.00
NA	-0.09	*	0.28	-0.07	0.18	0.30	0.13	0.02	-0.21	-0.68
SER	-0.12	*	-0.28	0.47	0.36	-0.04	0.28	0.47	0.33	0.07
SES	-0.22	*	-0.24	0.34	0.38	0.04	0.15	0.31	0.35	0.03
SEW	0.05	*	-0.04	0.11	-0.28	0.18	-0.14	0.00	0.27	0.47
FATIG	-0.23	*	0.13	-0.14	0.05	0.21	0.11	0.00	-0.16	-0.62
STRESS	-0.19	*	0.41	-0.30	-0.31	0.10	-0.34	-0.05	-0.17	-0.17

* Unable to calculate coefficient due to lack of variability in FUNCS

Correlation Matrix for Participant 4 (continued)

	NA	SER	SES	SEW	FATIG	STRESS
NA	1.00					
SER	-0.47	1.00				
SES	-0.51	0.88	1.00			
SEW	-0.60	0.52	0.57	1.00		
FATIG	0.81	-0.40	-0.44	-0.49	1.00	
STRESS	0.42	-0.18	-0.27	0.08	0.37	1.00

Correlation Matrix for Participant 5

	FUNCR	FUNCS	FUNCW	GASTR	TIB	QUAD	HAMS	SOT	LOS	PA
FUNCR	1.00									
FUNCS	-0.00	1.00								
FUNCW	0.08	0.23	1.00							
GASTR	-0.15	-0.36	-0.08	1.00						
TIB	0.11	0.34	0.17	-0.14	1.00					
QUAD	-0.01	-0.10	-0.09	0.44	0.07	1.00				
HAMS	-0.30	-0.12	-0.29	0.56	0.08	0.52	1.00			
SOT	-0.22	0.10	0.19	0.16	-0.02	0.44	0.24	1.00		
LOS	0.05	-0.05	-0.23	0.11	0.04	0.18	0.38	0.00	1.00	
PA	-0.13	0.07	0.10	0.22	0.12	0.12	0.12	0.17	-0.05	1.00
NA	0.23	-0.26	-0.08	0.12	0.31	0.24	0.08	-0.06	0.13	-0.22
SER	-0.02	0.10	0.02	-0.08	0.08	-0.09	-0.06	0.12	0.14	0.32
SES	0.00	-0.05	0.04	0.15	-0.03	0.12	0.44	0.18	0.15	0.17
SEW	-0.30	0.16	0.01	0.10	0.12	-0.05	0.31	-0.01	0.22	0.54
FATIG	0.15	-0.31	-0.12	0.12	0.10	0.31	0.30	-0.02	0.11	-0.37
STRESS	0.09	-0.45	-0.12	0.28	0.13	0.26	0.27	0.16	0.18	0.09

Correlation Matrix for Participant 5 (continued)

	NA	SER	SES	SEW	FATIG	STRESS
NA	1.00					
SER	-0.39	1.00				
SES	-0.03	0.10	1.00			
SEW	-0.22	0.23	0.53	1.00		
FATIG	0.59	-0.48	0.15	-0.16	1.00	
STRESS	0.52	-0.20	0.05	-0.04	0.62	1.00