Author Response
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We appreciate the opportunity to respond to Dr Di Fabio's commentary. We share his concerns about the use of information derived exclusively from studies of healthy subjects to establish criterion standards for the practice of physical therapy. We will address the main points raised in the commentary, along with additional considerations pertaining to the broader issue of the use of research findings from healthy persons.

Validity of the Outcome Measures and Their Relevance to Subject Performance

One of Dr Di Fabio's main concerns relates to our choice of the outcome measure. Our primary argument in this article was that an impulse-momentum approach, which provides data pertaining to measurements of center-of-mass momentum (CMM), can quantify a key balance requirement of sit-to-stand (STS). We were equally concerned with the validity and clinical utility of CMM as an outcome measure as we were with the reliability of the measurements.

A criterion measure is valid and useful only so much as it is reliable and relevant to the behavior being addressed. We cannot confirm the criterion-related validity of CMM measurements in this study because we did not compare our approach with some other test that would presumably measure the same thing, nor was that the purpose of our study. We did, however, quantify the output measures' reliability, which is the first step in judging the utility of a criterion measure.1

We believe that the output measures we used are highly relevant in light of issues concerning construct validity. The criterion measure CMM directly reflects a key balance requirement during STS. Because of the complexity of balance as a construct, few valid tests of balance (or its control) exist. The control of balance (maintaining the projected location or the trajectory of the center of mass within limits compatible with the base of support) during STS can be characterized by the impulse-momentum approach described in this and previous articles. The theoretical basis of this approach is derived from Newtonian mechanics (specifically, Newton's second law). It is the time-honored physical laws and mathematical principles that provide support for the construct validity of these CMM measurements.

We agree with Dr Di Fabio that by demonstrating differences in the CMM in patients versus healthy subjects, the criterion-related validity and its relevance as a criterion standard are strengthened. Based on the mechanical model described, we postulate that differences in CMM profiles during the performance of STS may exist in at least some persons with movement dysfunction, as we have shown for other tasks. The extent to which such differences affect performance remains to be established.

Relationship Between the Consistency of Measurements of Movement Performance and the Effectiveness of Physical Therapy Interventions

Dr Di Fabio also questions the validity of our suggestion that "an improved consistency of measurements of outcome may be a useful index of treatment efficacy." One time-honored approach to evaluating and understanding movement behavior has been the analysis of the consistency of movement outcomes as a function of practice.3 The consistency of movement performance is reflected in the measurement of the intraindividual variance of movement performance or outcome variables.

One significant change in movement performance that occurs normally with practice is that movement outcomes tend to become more consistent, as revealed by a decrease in intrasubject variability. That is, performance becomes more reliable. Such a change in task performance variability has been associated with the acquisition of motor skill. Moreover, changes in the intertrial consistency of measurements of movement performance with practice have been reported for a wide variety of motor tasks.8 There is also evidence6-8 to indicate that skilled performers demonstrate more highly consistent patterns of movement behavior in comparison with less skilled performers. As summarized by Schmidt, "these changes in movement pattern consistency represent some of the most persistent phenomena in the motor learning area."5

In view of this background information, our rationale for proposing that the consistency of key measurements of movement performance (eg, CMM during STS) may be a useful index of treatment efficacy is as follows. First, relatively high levels of intraindividual and interindividual variability of movement performance have generally been a hallmark characteristic for persons with disorders of movement function attributable to different pathologies, or to advancing age. Second, because reductions in performance variability due to practice have been widely associated with enhanced acquisition of motor skill, it is reasonable to expect that enhancement of movement function through physical therapy intervention might be reflected in decreased variability of movement performance. Third, intraindividual variability may normally be
correlated with functional performance levels of isometric strength, physical fitness, and speed of limb movement, suggesting a relationship between the reliability of performance and functionally relevant outcomes. There is no compelling reason to not suspect that similar relationships might exist for persons with disorders of movement function, or for other movement task variables. Fourth, the apparently powerful motor behavioral phenomena pertaining to skill acquisition warrant the identification and application of a normative model of task performance variability as a possible template against which to evaluate the recovery of movement function and effectiveness of physical therapy interventions.

What Is the Potential for Alternative Compensatory Strategies Involving Other Planes of Motion for Performing Sit-to-Stand?

Dr Di Fabio rightly points out that the STS transfer is not uniquely a sagittal-plane movement. Our focus on the sagittal plane, however, was guided by the inherent instability in this plane of motion during STS. The balance requirements in the anteroposterior direction are considerable because one moves from a relatively posteriorly located, wide, stable base of support to an anteriorly located, narrower base of support and transfers the center of mass from a low, initial position to a higher, terminal position.

The impulse-momentum relationship must be maintained despite potential body segmental differences in achieving STS. Specifically, despite changes in segmental mechanics (eg, joint torques), the center of mass must still be propelled from the chair forward and upward and subsequently slowed to maintain a final, balanced standing position. In the case of unilateral central nervous system lesions, it has been demonstrated that the individual propulsive impulses may differ significantly between sides during transitions from bipedal to single-limb stance, but the net effect of these differences is the successful generation of a resultant propulsive impulse that is essentially identical for movements in either direction. There is no reason not to suspect that similar principles apply to other planes of motion in situations in which individual limb impulses are asymmetrical during STS. Therefore, the fundamental mechanical requirements associated with certain CMM measurement characteristics do not appear to support the suggestion that "there are many ways to successfully achieve the standing position from a chair."

Questions arising from knowledge of the biomechanical principles underlying control of a key requirement during STS guided the choice of output variables. There are other kinematic approaches such as measurement of joint angular displacements that have been used to characterize the STS transfer. The utility, however, of describing the kinematics (eg, joint angular displacements) alone does not provide insights about the causes (eg, impulses) that generate such motion.

Is Research Using Healthy Subjects Unhealthy for the Practice of Physical Therapy?

Notwithstanding the legitimacy of several of the issues raised by Dr Di Fabio concerning our study, we question whether his view pertaining to the investigation of healthy subject performance reflects the broader editorial perspective of the Journal. We certainly agree with the point that "unimpaired-subject standards should not receive blanket acceptance." We found, however, that Dr Di Fabio's subordination of a major focus of our article (ie, the impulse-momentum relationship) neglected a critical factor in considering "whether some measure of performance in subjects without known pathologies, impairments, or disabilities is appropriate and relevant for use in a clinical assessment."

The generation of propulsive and braking impulses underlying CMM during STS does not merely reflect "the threshold level of magnitude and temporal variables" cited by Dr Di Fabio. Rather, the impulse-momentum relationship precisely specifies in quantitative, mechanical terms a critical movement performance outcome required to successfully complete an everyday functional task. In other words, if the impulse-momentum relationship described is not achieved (relevance), one does not successfully rise from a seated position (usefulness). The framework for the views raised in the commentary suggests an incomplete perspective on how one decides whether some measure of performance is appropriate and relevant for use in clinical decision making. If the expertise of a physical therapist resides in the evaluation and enhancement of human movement function, then knowledge of how movement is generated by healthy persons across the life span should equip the practitioner with valuable tools and insights for solving problems displayed by persons with disorders of movement function.

Finally, we also wonder whether there may be a mounting resistance on the part of the Journal to publishing research involving healthy subjects as the sole experimental group. Weinstein and Knecht rightly warn "a narrow view holds that any research that is not done in a clinical setting, with patients as subjects, is useless to the practice of physical therapy." The potential danger in such a view can be seen when taken to its logical, however absurd, conclusion. Would we not be calling into question the information provided by normal anatomy and physiology in physical therapy curriculums because the data gathered are derived from research that is not done in a clinical setting with patients as subjects? Moreover, should we be excluding examples of normal locomotion when teaching biomechanics because an understanding of normal movement behavior provides no direct information about how a patient might perform? Holding such a view should also raise questions about the use of animal studies that attempt to elucidate mechanisms of therapeutic approaches and interpret results in the context of patient care. Are data gathered from such studies inappropriate or useless be-
cause physical therapists do not treat that animal?

We trust that there may be a variety of views and opinions concerning these and related issues. It would be informative to know the perspectives held by the readership of the Journal pertaining to the timely issues raised by the thought-provoking commentary.

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References
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