characteristic of young, adult subjects.4 Furthermore, by not including measures of arm action, the authors strayed from what I would consider a description of whole-body movements in this task and may have wandered into the realm of relatively uncommon performance within the sit-to-stand task. Few people rise with the arms crossed in front of the body.

The subjects' feet were placed a set distance apart. This process, although ensuring the subjects' feet were on the force platform and adding "control" and consistency that will later allow comparison across studies, also gets rid of natural variability in the starting position, a factor demonstrated by Wheeler and colleagues5 to vary with age.

Despite the relative consistency of young adults when asked to perform multiple trials of a task, as a group adults demonstrate a high degree of interindividual variability. Kelley et al.,6 in their study of 6 subjects, commented on the across-subject variability in the rising pattern. Their subjects were able to use the upper extremities in performance of the task, and they identified shoulder and hip flexion as two sources of variability in the rising pattern. When Nusik et al.7 reported the results of their study of the sit-to-stand movements of more than 50 subjects, variability in movement patterns was again noted across subjects. I would suggest that the expressions of variability are just as informative for us as therapists and need to be explored before resorting to techniques of controlling the movement and mathematical smoothing of data. I am concerned that the second phase of rising identified by Schenkman et al may not be a general characteristic of sit-to-stand movements that include different starting postures and relative seat heights.

Do procedures designed to control subjects and their environments bring us closer to a meaningful description of rising motions? I would hesitate to propose they do at this point in our understanding of this movement pattern. The time is rapidly passing when we can legitimately use a sample of young adults to develop models of any movement pattern for clinical use with any group other than young adults. The hypothesis that variability in sit-to-stand movement is in part due to age-related processes has been investigated by comparing both elderly subjects4 and children4 with young adults. Those studies demonstrate that age differences do exist in the movement patterns used to rise from a chair. Five different arm patterns, three different head and trunk patterns, and three different leg patterns have been reported in a sample of just 10 young adults.4 These data demonstrate how very variable this movement pattern can be.

I would suggest, if the authors are going to use information such as that attained from this study to assess patients who have undergone knee replacement, that their normative data be generated using a relatively large number of subjects of similar age. I would suggest that 9 is an insufficient number of subjects to generate an average representation of any age group and that more than 30 to 50 subjects contributes very little to the descriptive process.

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Author Response

We appreciate Dr VanSant's thoughtful commentary on our work raising questions regarding the generalizability of this study. We are pleased to have this opportunity to respond to the comments of Dr VanSant, as there are some fundamental and conceptual issues that should be addressed. We will address the broad issue of choice of experimental approach and then discuss specific technical concerns that were raised.

Studies of human movement can be motivated by a variety of interests and questions. Some investigators have chosen to identify how people perform a particular activity during normal daily activities. These qualitative
and descriptive studies help us to appreciate the broad range of potential strategies that people use to carry out the same task. In this type of investigation, performance of the task is necessarily largely uncontrolled by the investigator. This approach is exemplified by the work of VanSant and colleagues.1-3

Other investigators are motivated by a desire to explicitly quantify the biomechanical features and constraints of a particular functional activity. This approach provides the basis for biomechanical models, with the potential of providing scientific explanations for the myriad of human motor behaviors identified by the first type of study. The work of Pai and Rogers,4 Riley et al,5 and Rodosky et al6 illustrates this approach to analysis of human behavior.

Some researchers have chosen to investigate performance of a task in order to make comparisons between groups of individuals or of the same individual over a period of time. Wheeler et al7 and Ikeda and colleagues (E Ikeda, M Schenkman, PO Riley, RW Mann, WA Hodge; manuscript in review) have applied this approach to the functional task of rising from a sitting position to a standing position. When analysis of human movement is used to make comparisons, we believe it is essential that the task or activity be explicitly described and adequately controlled in order to ensure reproducibility.

Each approach makes a distinct contribution to our knowledge of human movement. These approaches are furthermore complementary. For example, our analysis of momentum transfer in the sit-to-stand activity permits us to define the biomechanical components of the task. Hence, we can infer which impairments might preclude use of the strategy. We can also interpret the reasons for the many strategies of motion performance described in studies such as those of VanSant and colleagues.1-3

Our study was motivated by two of these three purposes. First, we wanted to establish a baseline for subsequent comparisons among individuals as they performed the sit-to-stand activity under controlled conditions.

Second, we wanted to make this a quantified biomechanical analysis of a particular movement strategy by combining precise three-dimensional kinematic data with foot-floor forces. We therefore needed to use a controlled protocol.

Some of Dr VanSant’s specific concerns relate to smoothing and averaging of the data. First, we contend that variability within and between subjects is not noise and therefore was not “smoothed out” by our processing techniques. Noise is spurious, unwanted additions to the true signal, which must be mitigated by techniques that engineers refer to as “smoothing” or “filtering.”8 We used high sampling rates to reduce the need for smoothing. The authenticity of kinematic data is enhanced, rather than diminished, by use of a high sampling rate. Averaging is a separate issue. We chose not to average our subject data because we did not want to lose subject-to-subject or trial-to-trial variability. By reporting frequencies of key events achieved during all 18 trials, we described the variability that occurred.

Another concern of Dr VanSant related to our choice of protocol. The highly controlled protocol with a uniform group of subjects maximizes the likelihood of achieving a consistent performance of the sit-to-stand activity. As described in our article, the variables we controlled have been shown, by previously reported investigations, to alter performance of the sit-to-stand task. The results of this study, and those of a companion study,9 illustrate the consistent kinematic and kinetic performance of the subjects who carried out this task. The combined results of these two studies have allowed us to elucidate a biomechanical model of the sit-to-stand activity. Thus, we believe we have achieved one of our two purposes.

Having established our test-performance baseline, we were then able to address our second purpose, which was to make performance comparisons to the sit-to-stand activity under the conditions of this controlled protocol. To this end, we have completed a comparison of healthy young and older individuals (E Ikeda, M Schenkman, PO Riley, RW Mann, WA Hodge; manuscript in review) and are currently comparing the performance of patients with Parkinson’s disease with that of healthy age-matched subjects. Our description of the biomechanics of this activity (presented in this article and in the companion study) provides us with the necessary basis for such comparisons.

To increase the generalizability of our investigations, we have also systematically varied some of the conditions under which subjects come to a standing position. For example, we have begun to study the influence of chair height, initial foot position, and speed of rising9 and are currently completing this investigation.

The sit-to-stand activity, as investigated in our article, has defined the necessary model for making objective, quantifiable comparisons between subjects. Through qualification of the kinematics and dynamics of the sit-to-stand activity, the laws of physics and mechanics can be applied to elucidate reasons for all of the limb-segment combinations of motion that investigators such as Dr VanSant have described.

In summary, this study should be read and interpreted from the perspective in which it was intended. Our motivation was to characterize an important, commonplace movement in such a way as to allow a biomechanical quantification of the task. This perspective precludes the use of our results to describe all possible strategies for rising from a chair. Our work does, however, allow us to use laws of mechanics and physics to interpret other descriptions of rising from a chair. Furthermore, our work allows us to make objective biomechanical comparisons between groups of individuals.
References


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