Rebuttal to Riek LM, Ludewig PM, Nawoczenski DA. How "healthy" is circuit resistance training following paraplegia? Kinematic analysis associated with shoulder mechanical impingement risk. J Rehabil Res Dev. 2013:50(6):861–74. http://dx.doi.org/10.1682/JRRD.2012.06.0112

Dear Editor:

This letter responds to the manuscript by Linda M. Riek, DPT, PhD, and colleagues entitled "How 'healthy' is circuit resistance training following paraplegia? Kinematic analysis associated with shoulder mechanical impingement risk," which was published in the November 6, 2013, edition of *JRRD* [1]. The purpose of their study was to determine whether wheelchair-based circuit resistance training (CRT) exercises for persons with chronic paraplegia expose the shoulders to risk for mechanical impingement. In pursuing the study goals, the investigators computed a mechanical impingement risk score for each of the six CRT exercises by combining scapular and glenohumeral kinematic and exposure data. When exercises for CRT were rank-ordered by impingement hazard, the (commonly named) "rickshaw" maneuver had the highest score and was therefore identified as posing the greatest risk.

As testing characteristics are noted by the authors to closely match those used in our training studies, and as our work was substantially cited, we felt that additional context for the study was warranted. Testing conditions described in the methods for resistance intensity (50% of one-repetition maximum) and contraction interval (6 s) were identical to those of several of our cited works [2–6], which might lead the reader to believe that other assessment conditions were similarly identical. However, such was not the case. **Figure 1(d)** of Riek et al. shows a setup for rickshaw testing where the arms appear somewhat distant from the body and forces are initially exerted near or behind the upper-body frontal plane [1]. Because the direction of the contraction is guided by the testing equipment and is primarily rotational, movement of the lever arm would first direct forces downward and then posterior-inferior. It is not surprising that this position would impinge, and this is appropriately described in the article. However, impingement may also be dependent on the limitation of scapular rotation achieved during motion, which is attributable to common fixation of the scapulothoracic articulation occurring after paralysis. This factor may also influence study outcomes but was not mentioned by the authors and is one reason we emphasize therapeutic mobilization of the scapula and training of subjects before beginning our conditioning protocols. Moreover, impingement noted by the investigators is likely made worse by the exaggerated forward-leaning posture of the study participant. By contrast, the equipment we use(d) for training (Equalizer 100, Helm; Bozeman, Montana) places the arms closer to the body and well forward of the frontal plane throughout the entire movement. The exercisers are also facing into the machine, not outward as shown in **Figure 1(d)**. In this respect, rotation during movement directs the arms anterior-inferior, even when the individual is slightly forward-leaning to obtain mechanical advantage. We emphasize similar mechanical form when using elastic bands for resistance [3]. For this reason, we suspect the CRT maneuver *per se* is less the problem and the user musculoskeletal status, positioning, and execution more so. Further, as noted by the authors, the Cybex Total Access equipment (Medway, Massachusetts) used for the study does not have adjustments in four of the five exercise stations tested to accommodate different wheelchair seat heights, which may put users in an unsafe position to proceed. Equipment used in our studies permits such adjustments for the rickshaw maneuver.

It is worth noting that the article provides no experimental evidence that the rickshaw maneuver is harmful, but rather invokes the greatest impingement score when rank-ordered against other maneuvers (although no statistical test of the difference in rank-order was conducted). A countervailing view might emphasize that the maneuver is required to execute weight shifts for pressure sore prevention and body transfers, which of course does not make the movement safe, just needed and commonly executed in daily life. To their credit, the investigators noted this need. Lastly, the article title alone might foster some curiosity that the CRT exercises are unsafe. Such a belief would be unsupported by the study findings and is counterbalanced by reported CRT-associated reduction in shoulder pain during activities of daily living when assessed by the population-validated Wheelchair Users Shoulder Pain Index, even when study participants began training with moderate upper-limb pain [4]. This published finding provides experimental evidence that the coalesced

CRT exercises are not innately harmful when users are appropriately qualified and pretrained to execute them properly and when all CRT exercises are judiciously set up and performed.

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RESPONSE

We thank Dr. Nash and Dr. Hicks for their comments on our article titled "How 'healthy' is circuit resistance training following paraplegia? Kinematic analysis associated with shoulder mechanical impingement risk" [1]. We appreciate the opportunity to discuss the critical issues highlighted in this article further. As previously emphasized in our article [1], exercise is essential to prevent the secondary complications associated with spinal cord injury (SCI), including but not limited to obesity, diabetes mellitus, and cardiovascular disease. Due to lower-limb paralysis, it is a reality that individuals with paraplegia may be restricted to already overtaxed upper limbs to execute these vital exercises. Given that up to 83 percent of individuals with paraplegia describe shoulder pain since beginning wheelchair use [2–3] and its effect on functional independence, shoulder health cannot be relegated in importance. Instead, exercises must be selected judiciously that target secondary complications of SCI while simultaneously respecting shoulder health.

The premise for this project was to allow individuals with paraplegia to participate in a real-life community fitness center. As opposed to creating a "testing environment," we purposefully mimicked the everyday realistic setting experienced by wheelchair users in our community. Participants remained in their own custom wheelchairs and utilized the CRT equipment that was available (Cybex Total Access; Medway, Massachusetts, and Endorphin Parallel Dip; Pinellas Park, Florida). We are in agreement with Dr. Nash and Dr. Hicks that *position*, which is dictated and guided by the confines of specific CRT equipment, may increase the risk of mechanical impingement. Of the exercises performed, the rickshaw (Endorphin Parallel Dip), as illustrated, was highlighted as the exercise of most concern because it had the greatest combination of both magnitude and exposure corresponding with subacromial impingement risk. However, we differ from Dr. Nash's and Dr. Hicks's perspective that the rickshaw maneuver is required to execute weight shifts for pressure prevention and transfers. Although adequate muscle

strength is needed to perform a functional task, targeted muscle strengthening does not necessitate replicating the functional maneuver *exactly* in an exercise, especially if already performing that functional task or if the exercise increases mechanical impingement risk. Additionally, we do not concur that the title of the article implies that CRT exercises are unsafe. Instead, the title, posed as a question, encourages the reader to consider *what* exercises are being performed and *how* the exercises are being performed with regard to shoulder health. As emphasized throughout the article, the ultimate goal is to guide shoulder-healthy CRT recommendations for individuals with paraplegia. We believe Dr. Nash and Dr. Hicks share this goal.

This investigation was the first to evaluate shoulder kinematics during the execution of wheelchair-based upper-limb exercises and is essential in providing the foundation for future projects. Future articles will demonstrate how simple hand modifications, including hand position, can positively affect kinematics during execution of CRT. This will allow CRT training to continue with reduced mechanical impingement risk. Additionally, investigations incorporating three-dimensional modeling are needed to *directly* assess scapulothoracic and glenohumeral angular positions on the subacromial space. Finally, only three interventions to date have been trialed with the primary purpose of reducing shoulder pain following SCI [4–6]. Considering functional needs, large-scale investigations need to address which exercises, and at what dosage, are most effective in treating and preventing shoulder pain.

Thank you for giving us the opportunity to respond to this Letter to the Editor. It is our hope that the discussion encourages further research on this very important topic.

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