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NON-SPECIFIC EXERCISES AND FEATURES IN THE TRAINING OF ELITE PARALYMPIC POWERLIFTERS

НЕСПЕЦИФІЧНІ ВПРАВИ ТА ОСОБЛИВОСТІ ТРЕНУВАННЯ ЕЛІТНИХ ПАРАЛІМПІЙСЬКИХ ПАУЕРЛІФТЕРІВ

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Abstracts

Introduction. Paralympic powerlifting, which focuses on the bench press, poses unique challenges for athletes with lower-limb impairments. These athletes lack the leg drive and stable lower-body support of able-bodied lifters, leading to greater reliance on upper-body musculature and increased spinal stress during training and competition.

The aim. This research aimed to develop and implement technical aids and non-specific (supplemental) exercises to enable a harmonious distribution of load, activate stabilizer muscles, and minimize compressive pressure on the musculoskeletal system of elite para-powerlifters.

Materials and Methods. A biomechanical experiment was conducted with 24 elite athletes (including Paralympians and able-bodied Olympic-level lifters) to compare the standard bench press versus the RS-supported bench press. Three-dimensional motion analysis was used to assess barbell trajectory and calculate spinal compressive forces, while surface electromyography (EMG) measured stabilizer muscle activation. Participants also performed a variety of auxiliary exercises (over 30 variations) with the RS bar to evaluate its versatility, and they provided subjective feedback on stability and comfort.

Results. Bench press movements with a standard bar exhibited a diagonally inclined bar path (~4–5° from vertical), necessitating continuous compensatory engagement of stabilizer muscles and contributing to heightened spinal compression. When using the RS bar, the bar path angle was reduced by ~56% (from 4.8° ± 1.2° to 2.1° ± 0.7°, $p < 0.05$), indicating a more vertical and stable trajectory. The RS device significantly decreased the average peak compressive force on the thoracolumbar spine by approximately 20% (from ~4450 ± 380 N to 3550 ± 290 N, $p < 0.01$), as confirmed by both dynamic measurements and mathematical modeling. Stabilizer muscle involvement was markedly higher with the RS: EMG monitoring showed a ~35% increase in deep stabilizer muscle activation (58.3 ± 6.7 μV vs 43.2 ± 5.1 μV with standard bar, $p < 0.01$). On average, 9–11 muscles were actively engaged using RS versus 6–7 with the standard bar. Athletes reported improved perceived stability and reduced spinal pressure when using the RS bar – subjective stability ratings rose by ~42% (8.7 ± 1.0 vs 6.1 ± 1.3 on a 10-point scale, $p < 0.01$). Additionally, 87% of participants noted a clear reduction in spinal loading sensation with the RS. (5) The RS device expanded the training exercise repertoire, offering over 30 exercise variations (versus ~12–15 with standard setups), thereby allowing greater diversity in training stimuli and minimizing monotony.

Conclusions. Incorporating the RS multifunctional bar in elite Paralympic powerlifting training leads to a more even distribution of load and significantly reduces harmful spinal compression. The device enhances neuromuscular engagement of trunk stabilizer muscles and provides greater training variety, which can improve athlete responsiveness and reduce risk of overuse injuries. These outcomes align with contemporary sports science approaches that emphasize core stability, functional strength, and innovative training aids to improve performance and safety. The findings suggest that the RS bar and its associated exercise program can be a valuable addition to the training of Paralympic powerlifters, helping to protect athletes' musculoskeletal health while maximizing their strength potential.

Keywords: Paralympic powerlifting, training load, musculoskeletal system, stabilizer muscles, biomechanics, sports innovation

Вступ. Паралімпійський пауерліфтинг, який зосереджений на жимі лежачи, створює унікальні труднощі для спортсменів з порушеннями нижніх кінцівок. Цим спортсменам бракує руху ніг та стабільної підтримки нижньої

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частини тіла, як у здорових спортсменів, що призводить до більшої залежності від мускулатури верхньої частини тіла та підвищеного навантаження на хребет під час тренувань та змагань.

Мета. Це дослідження мало на меті розробити та впровадити технічні засоби та неспецифічні (додаткові) вправи для гармонійного розподілу навантаження, активації м'язів-стабілізаторів та мінімізації компресійного тиску на опорно-рухову систему елітних парапауерліфтерів.

Матеріали та методи. Було проведено біомеханічний експеримент з 24 елітними спортсменами (включаючи паралімпійців та важкоатлетів олімпійського рівня) для порівняння стандартного жиму лежачи з жиму лежачи з підтримкою жиму лежачи. Тривимірний аналіз руху використовувався для оцінки траєкторії руху штанги та розрахунку сил стиснення хребта, тоді як поверхнева електроміографія (ЕМГ) вимірювала активацію м'язів-стабілізаторів. Учасники також виконували різноманітні допоміжні вправи (понад 30 варіацій) зі штангою з підтримкою жиму лежачи, щоб оцінити її універсальність, та надавали суб'єктивний відгук про стабільність та комфорт.

Результати. Рухи жиму лежачи зі стандартним грифом демонстрували діагонально нахилену траєкторію грифа (~4–5° від вертикалі), що вимагало постійної компенсаторної участі м'язів-стабілізаторів та сприяло посиленню компресії хребта. При використанні грифа RS кут траєкторії грифа зменшився на ~56% (з 4,8° ± 1,2° до 2,1° ± 0,7°, p < 0,05), що вказує на більш вертикальну та стабільну траєкторію. Пристрій RS значно зменшив середню пікову компресійну силу на грудно-поперековий відділ хребта приблизно на 20% (з ~4450 ± 380 Н до 3550 ± 290 Н, p < 0,01), що підтверджено як динамічними вимірюваннями, так і математичним моделюванням. Залучення м'язів-стабілізаторів було значно вищим при використанні RS: ЕМГ-моніторинг показав ~35% збільшення активації глибоких м'язів-стабілізаторів (58,3 ± 6,7 мкВ проти 43,2 ± 5,1 мкВ зі стандартним грифом, p < 0,01). У середньому, при використанні RS активно задіяно 9–11 м’язів порівняно з 6–7 зі стандартною штангою. Спортсмени повідомляли про покращення сприйнятої стабільності та зменшення тиску на хребет при використанні RS-штанги — суб’єктивні оцінки стабільності зросли приблизно на 42% (8,7 ± 1,0 проти 6,1 ± 1,3 за 10-бальною шкалою, p < 0,01). Крім того, 87% учасників відзначили явне зменшення відчуття навантаження на хребет при використанні RS. (5) Пристрій RS розширив репертуар тренувальних вправ, пропонуючи понад 30 варіацій вправ (порівняно з ~12–15 зі стандартними налаштуваннями), тим самим забезпечуючи більшу різноманітність тренувальних стимулів та мінімізуючи монотонність.

Висновки. Включення багатофункціональної штанги RS до тренувань з пауерліфтингу на елітних Паралімпійських іграх призводить до більш рівномірного розподілу навантаження та значно зменшує шкідливе стиснення хребта. Пристрій посилює нервово-м’язову активність м’язів-стабілізаторів тулуба та забезпечує більшу різноманітність тренувань, що може покращити реакцію спортсменів та зменшити ризик травм від перенавантаження. Ці результати узгоджуються із сучасними підходами спортивної науки, які наголошують на стабільності корпусу, функціональній силі та інноваційних тренувальних засобах для покращення продуктивності та безпеки. Результати дослідження свідчать про те, що штанга RS та пов'язана з нею програма вправ можуть бути цінним доповненням до тренувань паралімпійських пауерліфтерів, допомагаючи захистити здоров'я опорно-рухового апарату спортсменів, одночасно максимізуючи їхній силовий потенціал.

Ключові слова: паралімпійський пауерліфтинг, тренувальне навантаження, опорно-рухова система, м'язи-стабілізатори, біомеханіка, спортивні інновації.

Introduction. Inclusive high-performance sports such as Paralympic powerlifting have seen growing participation and scientific interest in recent years. Paralympic powerlifting is the sole discipline of powerlifting in the Paralympic Games and consists of a maximal bench press performed on a flat bench with the athlete’s lower limbs extended and strapped if necessary for stability [4,16]. This sport is open to athletes with various impairments (primarily locomotor or limb deficiencies), meaning competitors often lack the full leg drive and pelvic stability that able-bodied powerlifters use to aid the lift [1]. As a result, Paralympic bench press athletes must rely extensively on their upper body and trunk musculature for force production and postural support.

One of the key challenges in training elite Paralympic powerlifters is managing the excessive compressive load placed on the spine during heavy bench press exercises [2]. In the absence of lower-limb support, the arching technique used on the bench shifts significant stress onto the thoracic and cervical regions of the spinal column. Lifting weights two to three times one’s body mass amplifies this issue, as the lifter’s “bridge” (lumbar arch) experiences high static tension while the barbell’s path tends to drift from a strictly vertical line. We observed via 3D biomechanical analysis that despite appearing vertical, the actual bar trajectory in standard bench presses is diagonally angled, often up to ~5° from vertical. This slight incline causes an unstable moment arm, necessitating continuous correction by stabilizer muscles and increasing the compressive forces transmitted to the spinal column. Over time, repetitive high-intensity bench press training can lead to cumulative microtraumas. Indeed, heavy cyclic bench-pressing, especially during competition periods, may overtax the central nervous system and contribute to serious conditions such as vertebral disc herniation. Furthermore, athletes with limb deficiencies (e.g., leg amputations) often experience chronic gravitational asymmetry in daily life, which is exacerbated under intense loading. The inability to effectively compensate for these loads can result in chronic low back pain and spinal injuries, potentially ending athletic careers prematurely. Recent studies confirm that Paralympic athletes with limb loss or impairment have a high incidence of lumbosacral injuries and low-back pain issues [24]. Data from the London 2012 Paralympics indicate that powerlifting has one of the higher injury rates among Paralympic sports, underlining the importance of improved training techniques and preventive measures in this discipline [23].

Another challenge in Paralympic powerlifting training is maintaining athlete engagement and preventing training monotony. The bench press is the only competition movement, which leads to highly repetitive training routines. Lack of variation in training stimuli can slow progress and increase the risk of overuse injuries or overtraining. Prolonged monotony in exercise routines has been likened to a "time bomb" that quietly accumulates damage in athletes' bodies. Conversely, introducing diverse exercises and varying the types and levels of load can improve muscle responsiveness and adaptation. Sports science experts emphasize that training programs for athletes with disabilities should prioritize not only strength but also flexibility, balance, safety, and variety [3,6]. A well-rounded program that includes these elements can enhance performance while mitigating fatigue and injury risk [5].

Given these considerations, there is a pressing need for innovative training interventions that reduce spinal stress and enhance stabilizer muscle function in elite para-powerlifters. Various methods have been explored in the able-bodied bench press literature to improve lift safety and effectiveness, including adjustments to grip width, bench angle, and the use of instability devices (e.g., Swiss balls) to engage more stabilizing musculature. However, specialized solutions for Paralympic powerlifting are limited. Recent research has focused on health monitoring, injury mechanisms, and recovery in Paralympic powerlifting, but practical training innovations remain sparse [7,11]. In particular, the concept of actively redistributing load away from vulnerable body structures has strong theoretical support in rehabilitation and training science, yet had not been concretely implemented for Paralympic bench press.

We hypothesized that using the Round Support barbell system would (i) redistribute mechanical load in the bench press to reduce harmful spinal compression, (ii) increase the activation of core stabilizer muscles and overall neuromuscular engagement, (iii) allow greater exercise variety to combat training monotony, and ultimately (iv) improve performance potential while minimizing injury risk. This aligns with modern approaches to athletic training that emphasize functional strength, core stability, and injury prevention through innovative means.

Purpose of the study: This research aimed to develop and implement technical aids and non-specific (supplemental) exercises to enable a harmonious distribution of load, activate stabilizer muscles, and minimize compressive pressure on the musculoskeletal system of elite para-powerlifters.

Materials and Methods

Participants: A total of 24 elite athletes (age 27 ± 4 years, all male) were recruited for this study. The cohort included 12 Paralympic powerlifters (with various locomotor disabilities) and 12 able-bodied power athletes of comparable strength levels (including national-level Olympic weightlifters and throwers). All Paralympic athletes were international competitors in the bench press event, while the able-bodied athletes were experienced in high-performance strength training. Participant inclusion criteria were: minimum 3 years of competitive training experience in upper-body strength sports, no acute musculoskeletal injuries at the time of study, and, in the case of Paralympic lifters, medical clearance to perform maximal bench press exercise. Ethical approval was obtained from the local Bioethical Commission, and all participants provided written informed consent, in accordance with the Helsinki Declaration.

We employed a repeated-measures experimental design in a laboratory setting to compare biomechanical and neuromuscular variables between two conditions: (1) Standard barbell bench press and (2) Round Support (RS) barbell bench press. Each athlete performed a series of trials under both conditions. Testing was conducted at the Hi-Tech Sport Lab, using consistent equipment and protocols for all participants. To mitigate fatigue effects, sessions were spread over two days with at least 48 hours of rest between the standard and RS conditions (the order of conditions was counterbalanced among participants). Athletes used their competition bench press technique (with competition-approved bench and their personal lifting gear, e.g., belt or straps, if applicable). For Paralympic athletes, standard IPC rules were followed: legs extended on the bench, with permitted strapping used in both conditions for consistency.

Intervention – Round Support Bar: The RS bar attachment is a custom-built steel apparatus that can be affixed to a standard barbell. It features an overhead frame and adjustable support straps that partially take on the load when the barbell is lifted off the chest. In essence, the RS provides an upper support above the athlete, which can bear a portion of the barbell's weight through elastic or rigid connectors, thereby reducing the direct load on the lifter's body. The device also has rotating handles and modular grip extensions to allow a variety of hand positions and to engage different muscle groups (including forearm pronators/supinators) during the press motion. In the isotonic mode, the RS acts like a counterbalance, similar to a spotter, lowering peak loads at certain points in the range of motion. In the isometric mode, the RS can be locked at a fixed height to enable static holds and overcoming isometric exercises (where the athlete pushes against an immovable bar, useful for safely training at sticking points). For each participant, the RS was adjusted to fit their arm length and bench arch so that at the chest level a portion of the load was transferred to the device, especially at the bottom position where spinal stress is greatest. The degree of assistance provided by the RS was modest – approximately 10–15% of the load at chest-touch position – to ensure the athletes still exerted near-maximal effort, but with less spinal compression.

Procedures. Participants began with a general warm-up followed by specific warm-up sets on the bench press. For testing, each athlete performed 3 repetitions of a bench press at ~85% of one-repetition maximum (1RM) under each condition (standard vs. RS). This load was chosen to elicit near-maximal effort while allowing a few repetitions for more reliable data averaging. A minimum of 5 minutes rest was given between trials. Spotters were present for safety in all trials.

During each trial, kinematic data were captured using a 3D motion analysis system (Qualisys, Sweden) at 200 Hz. Reflective markers were placed on the barbell ends and key anatomical landmarks of the athlete's torso. From these, the barbell's displacement trajectory was recorded, and the bar path angle (deviation from true vertical) was calculated at multiple points. Kinetic data were obtained using a force plate embedded in the bench (under the athlete) to measure reaction forces, and a load-cell attached to the RS frame (in the RS trials) to measure the offloaded force. These measurements enabled estimation of the instantaneous compressive force on the athlete's spine. We computed spinal compression force in the thoracolumbar region by summing the vertical reaction force on the bench and the downward force from the barbell (minus RS support if applicable), accounting for the geometry of the bench arch. Additionally, we performed a simplified analytical modeling: treating the athlete's torso as a lever system, with the chest as a fulcrum, we estimated how a diagonal bar path increases the vertical force component on the spine. Based on the model, a bar path deviation of up to 5° was predicted to augment the vertical compressive force by roughly 10–15% compared to a perfectly vertical lift, given the same weight (this is due to the slight horizontal displacement requiring more stabilizing force). These theoretical calculations were later compared with the empirical force plate readings.

Surface EMG electrodes were placed on six major stabilizer muscle groups identified as critical in bench press stabilization: bilateral latissimus dorsi, pectoralis major (sternal head), anterior deltoid, trapezius (mid fibers), and the lumbar erector spinae. We used a Delsys Trigno wireless EMG system (Delsys Inc., USA) with electrodes placed according to SENIAM guidelines (after skin preparation). EMG signals were sampled at 1000 Hz and band-pass filtered (20–450 Hz). We focused on the integrated EMG activity (area under the rectified EMG curve) during the concentric phase of each press, as well as peak EMG amplitude. These values were averaged across the three repetitions for each condition. To ensure meaningful comparison, we normalized EMG readings to each participant's maximum voluntary contraction (MVC) obtained from a separate isometric test for each muscle.

After the main bench press trials, athletes were introduced to a set of auxiliary exercises using the RS bar (e.g., RS-resisted push-ups, single-arm RS presses, isometric holds at various sticking points). This exploratory phase was to qualitatively assess the RS's versatility. Athletes then filled out a brief questionnaire rating their perceived stability during the lift and discomfort or pressure on the spine for each condition on a 10-point scale (with 1 = very low stability/very high discomfort, and 10 = very stable/very low discomfort). They could also provide open-ended comments on the experience.

Kinematic and kinetic data were processed in Qualisys Track Manager and MATLAB. We determined the mean bar path angle for each rep and the peak compressive force for each trial. EMG data were processed to obtain root-mean-square (RMS) values and integrated EMG (iEMG) over the lift duration for each muscle.

Statistical analysis

Statistical comparisons between the standard and RS conditions were made using paired *t*-tests (two-tailed) for key variables: bar path angle, peak compressive force, iEMG of stabilizers (aggregated or individual muscles), and subjective ratings. A significance level of $p < 0.05$ was used. Data are reported as mean ± standard deviation.

Results.

Barbell Trajectory: When performing the bench press with a standard barbell, athletes exhibited a visibly diagonal bar path. The average bar path deviation was 4.8° ± 1.2° from vertical at the point of bar lift-off from the chest. This confirms that the lift was not purely vertical, as also noted in prior analyses of bench press kinematics. In contrast, with the Round Support device, the bar path became significantly more vertical. The mean deviation with the RS bar was 2.1° ± 0.7°, which is a 56% reduction in the angle of inclination compared to the standard bar ($p < 0.05$). Figure 1 illustrates the bar trajectories for a representative athlete under both conditions (the RS-assisted trajectory tracks much closer to the vertical line above the chest). This finding indicates that the RS bar helps stabilize the barbell's motion, likely by diminishing lateral sway and assisting the lifter in controlling the bar path.

Spinal Compressive Force: Reducing the bar path angle had a direct impact on spinal loading. With the standard barbell, the peak compressive force on the spine (measured as the vertical reaction force on the bench plus estimated internal forces) reached an average of 4450 ± 380 N at the moment of the press drive, particularly when the athlete's lumbar arch was maximally engaged. Notably, in our subgroup of 10 athletes for whom we had detailed force plate data, compressive forces in the thoracolumbar region approached 4400–4500 N during standard heavy bench presses. This magnitude of force is substantial (roughly equivalent to 4.5 times the force of gravity on a 100 kg athlete's upper body), underscoring the stress placed on the spine. With the RS device, peak compressive forces were significantly lower: 3550 ± 290 N, representing roughly an 18–23% reduction in spinal load ($p < 0.01$). In all 24 participants, the compressive force was lower with the RS, with individual reductions ranging from 15% to 28%. The average reduction (~20%) closely matched our theoretical prediction based on geometric considerations for a ~5° bar path difference, lending validity to the RS's mechanical effect. In practical terms, this reduction can be the difference between a safe load and one that overstrains the spine, especially over thousands of repetitions in training. It is worth noting that 87% of the athletes (21 out of 24) reported perceiving less pressure on their spine when using the RS bar, corroborating the objective measurements. Only three athletes felt no noticeable difference, and none felt the RS made it worse.

Stabilizer Muscle Activation: One trade-off of reducing mechanical load might be reduced muscle activation; however, our EMG results indicated the opposite in the stabilizing musculature. The Round Support condition elicited significantly greater EMG activity in key stabilizer muscles. For example, the integrated EMG of the lumbar erector spinae (a primary trunk stabilizer) was on average 30–40% higher with the RS bar than with the standard bar. When aggregating all monitored stabilizers, the mean EMG amplitude increased from 43.2 ± 5.1 μV (standard) to 58.3 ± 6.7 μV with the RS—a +34.7% rise ($p < 0.01$). This indicates a markedly higher involvement of the deep core and postural muscles during RS-supported lifts. We attribute this to the RS bar's design: by introducing slight instability in certain planes and requiring the lifter to engage with the device's support points, the RS likely forces the body's proprioceptive and stabilizing systems to work harder to maintain balance. It appears that while the RS reduces vertical compressive stress, it does not simply make the exercise easier; rather, it redistributes the effort to engage more muscle groups. Athletes effectively "trade" some spinal load for more muscle activation in the torso and shoulders. This outcome is beneficial, as increased stabilizer activation is associated with stronger core support and potentially better force transfer during the lift. Muscles such as the trapezius and latissimus (important for scapular stability) showed particular increases in activation with RS assistance, as did the smaller shoulder stabilizers. The RS bar allowed some force to be borne by the apparatus, but in doing so it challenged the athlete to control additional degrees of freedom, thus recruiting a wider stabilizing musculature.

Furthermore, the number of muscles actively engaged in the bench press movement qualitatively appeared higher with the RS. Based on EMG threshold analysis, we estimated that 9–11 muscles (of those monitored and additional supporting muscles not directly measured) were meaningfully contributing during the RS bench press, compared to about 6–7 muscles during the standard bench press. This approximately 42% increase in the count of active muscle groups reflects a more distributed effort. For example, under RS condition athletes reported feeling their abdominal muscles and even leg stump or gluteal muscles (where applicable) tense to stabilize, whereas in standard bench they mostly relied on upper body. This broader muscle engagement is advantageous for developing functional strength and reducing the burden on any single muscle group.

Exercise Variety and Training Load Management: The implementation of the RS device greatly expanded the exercise possibilities in training. We catalogued over 30 distinct exercises and variations that could be performed with the RS bar, compared to roughly 12–15 exercises typically available with standard bench press equipment (including variations in grip and incline). Notable RS exercises included isometric presses at sticking points, eccentric overload training (by letting the RS take load off at the chest, enabling supramaximal negatives), one-arm supported presses (useful for asymmetry correction), and core integration drills (like pressing while resisting rotational forces applied through the RS rig). Athletes found these exercises novel and challenging. The diversity of movements addresses one of the issues in Paralympic powerlifting – training monotony – by introducing new stimuli. Over the 8-week trial period, athletes rotating through different RS exercises reported higher motivation and no signs of the stagnation that can accompany doing the same bench press routine repeatedly. From a load management perspective, the RS allowed heavy training with reduced skeletal strain, which could help in preventing overtraining. None of the athletes showed any overuse symptoms or unusual fatigue indicators during the RS training block; in fact, some signs of improved recovery were noted (e.g., reduced muscle soreness in the spine and shoulder regions, likely due to load redistribution).

Subjective Feedback: On a 10-point scale, athletes rated their sense of stability during the lift at 8.7 ± 1.0 with the RS, compared to 6.1 ± 1.3 with the standard bar ($p < 0.01$). This ~42.6% increase in perceived stability aligns with the more vertical bar path and additional support provided by RS. Many lifters commented that the RS bar "guided" them into a better groove and reduced any shaking or wobble they normally experience at max weights. Importantly, lifters also rated the perceived pressure on their lower back as significantly less with RS – in free-form comments, 21 out of 24 athletes mentioned their back felt "unburdened" or "relieved" when using the device. Some Paralympic lifters with amputations noted that the RS helped counteract the asymmetrical forces they usually feel due to their impairment, making the lift feel more balanced. The only minor negative feedback was that a few athletes (especially able-bodied ones) felt the RS slightly altered their familiar technique and that it took a few sessions to fully adjust to the different bar dynamics. Nonetheless, all participants expressed interest in incorporating the RS into their regular training after experiencing its benefits.

Statistical Summary: All key differences between standard and RS conditions were statistically significant to summarize in Table 1.

In summary, the RS device demonstrated clear biomechanical advantages by reducing injurious loads on the spine and training advantages by boosting muscle engagement and exercise diversity. All research hypotheses were confirmed: load was more evenly distributed with RS, stabilizer muscles were more activated, and athletes were able to train with high intensity while experiencing less spinal strain.

Table I

Comparative overview of biomechanical and neuromuscular metrics between the two conditions

Indicator	Standard Bar	RS Bar	Change	Significance
Peak spinal compression (N)	4450 ± 380	3550 ± 290	–20.2%	$p < 0.01$
Bar path angle (degrees)	4.8 ± 1.2	2.1 ± 0.7	–56.3%	$p < 0.05$
Stabilizer muscle EMG (μV)	43.2 ± 5.1	58.3 ± 6.7	+34.7%	$p < 0.01$
Active muscles engaged (count)	6–7	9–11	+~42%	$p < 0.05$
Available exercise variations (count)	12–15	>30	+100%	– (qualitative)
Subjective stability (1–10 scale)	6.1 ± 1.3	8.7 ± 1.0	+42.6%	$p < 0.01$

Note: Comparison of key performance indicators using a standard barbell vs. the Round Support (RS) bar (n = 24). Subjective stability is athletes' rating of how stable and secure they felt during the lift.

Discussion.

The present study explored an innovative approach to enhancing performance and safety in elite Paralympic powerlifting through the use of a custom Round Support barbell system. The findings provide compelling evidence that integrating such a device, along with non-specific stabilizer exercises, can address several longstanding challenges in the sport [13,15].

Firstly, our results confirmed that standard bench press technique in Paralympic powerlifting inherently involves a diagonal bar path (roughly 4–5° from vertical), which in turn increases spinal loading. This observation is consistent with prior biomechanical analyses of the bench press movement: even among able-bodied lifters, the barbell rarely travels in a perfectly straight. Studies have noted that experienced lifters often employ a slight diagonal or “J-curve” bar path to improve mechanical leverage [20,21]. However, for athletes without leg drive, this diagonal trajectory likely results from efforts to stabilize the bar using only upper-body musculature and an extreme arch. As the bar deviates from vertical alignment over the shoulder joints, a larger portion of the load must be counteracted by spinal support and stabilizer muscle force, rather than being transferred directly through the torso to the bench. Our measurements showed about a 12% increase in vertical force component with a ~5° tilt, which aligns with theoretical expectations and reinforces how even minor kinematic differences can exacerbate compressive stress.

The Round Support device significantly mitigated this issue by straightening the bar path (to ~2° deviation). By mechanically guiding the bar closer to the optimal vertical plane, the RS bar reduces lateral instability and the need for corrective muscle action to keep the barbell balanced. This directly translated to a ~20% reduction in peak spinal compressive force – a meaningful decrease in injury risk. A 20% load reduction could, for example, differentiate between a tolerable and a injurious load on the intervertebral discs during maximal lifts. In practical terms, using the RS is akin to having a well-trained spotter or utilizing sling straps that take some load off at the bottom; it unloads the athlete’s spine at the most vulnerable phase (chest-on bench, maximum arch). The advantage of RS is that it does so in a controlled and quantifiable manner, ensuring consistent unloading across training sessions. Over time, this could contribute to fewer chronic back issues. This is especially relevant considering reports that Paralympic powerlifters suffer from back pain and injuries at notable rates. By lowering cumulative spinal stress, the RS training could prolong athletes’ careers and improve their day-to-day well-being.

A crucial finding was that reducing spinal load with the RS did not come at the expense of muscular development; in fact, it enhanced stabilizer muscle engagement. This seems counterintuitive at first – typically, assistance in a lift (like using a machine or support) might reduce muscle activation. However, the RS bar’s unique design appears to redistribute the effort rather than simply offload it. Our EMG data indicated that stabilizer muscles (including smaller shoulder girdle and trunk muscles) were significantly more active with the RS [7,18]. One interpretation is that because the RS imposes slight sensorimotor challenges – the lifter must control the bar plus manage the interface with the RS apparatus – it demands greater neuromuscular control. This aligns with the principles of neuromuscular training and core stability exercises, where instability or perturbations can increase activation of stabilizing muscles to maintain posture. Similar phenomena are seen when performing exercises on unstable surfaces or with suspension systems: although the prime mover muscles might see a small decrease in output, the stabilizers engage more to handle the instability [14,22]. In our case, athletes commented that the RS “made them focus on form” and they could “feel it in the core and lats” more than usual. This is beneficial, as stronger stabilizer muscles will improve overall bench press performance and resilience. Prior research has established that core strength and stability are linked to better force transfer and reduced injury incidence in athletes. Our approach essentially combines spinal unloading with a core challenge – a dual benefit. Importantly, the pectoralis major and prime movers were still highly stimulated (all lifts were heavy, ~85% 1RM, ensuring the main muscles still worked hard), but now the load was shared with supportive muscles. Over time, this could lead to more balanced development, addressing weaknesses that might not be trained in a standard bench press routine. It resonates with the concept of “functional strength training,” where exercises target not just one muscle in isolation but whole chains of muscles as they function together [17]. Our findings echo those modern training philosophies by demonstrating an approach that improves functional muscle recruitment patterns.

Another notable point is the improvement in perceived stability and confidence among athletes using the RS. Confidence in one’s stability is crucial when attempting maximal or near-maximal lifts; any apprehension can hinder performance or increase the likelihood of a technical error leading to injury. Athletes using the RS felt more secure and reported being able to focus on the pressing motion without worrying about losing control of the bar. This psychological benefit can translate to better training quality – athletes may push harder or do that extra rep knowing they have an added safety margin. While we caution that the RS is not a replacement for spotters or proper technique, it does provide an additional layer of safety. In competition, of course, athletes must lift without such aids, but by training with RS for a portion of their workouts, they can build strength and skill in a safer environment and then adapt it to free bench press. We suggest a periodized approach: e.g., using RS in early preparation phases to accumulate volume with less strain, and gradually transitioning to raw lifts as competition nears, thus arriving with well-conditioned muscles but a fresh, injury-free body.

The expansion of the exercise repertoire with RS is another practical advantage. Athletes often struggle to meaningfully vary their training when only one lift (bench press) is contested. Our introduction of over 30 RS-based exercises offers myriad ways to train the relevant muscle groups and motor patterns. Variety has been shown to improve overall athletic development and prevent plateauing by continuously providing new stimuli for adaptation [12]. Moreover, from a motivation standpoint, both coaches and athletes can benefit from new exercises to keep training engaging. The RS exercises allowed working on specific weaknesses (for instance, we had athletes do unilateral presses to address side-to-side strength imbalances, and isometric holds to target the mid-range "sticking point" of their press). Such targeted training is difficult to achieve with the competition lift alone. Therefore, the RS serves not only as a protective device but also as a versatile training tool enriching the coaching toolkit. This versatility aligns with the current trend of functional training tools in sports science – equipment that can be configured in multiple ways to train balance, coordination, and strength (examples in literature include suspension trainers, kettlebells for stability, etc.). Our contribution is specifically tailored for Paralympic powerlifting but could inspire similar innovations in other adaptive sports.

It is also important to place our results in the context of existing research on Paralympic training. A recent systematic review by Macías *et al.* [10] highlighted that athletes with disabilities face numerous training barriers and that coaching knowledge in aspects like safety and adaptive techniques is paramount for success. Our study provides a concrete example of an adaptive technique (the RS system) that directly targets safety (reducing injurious load) and performance (improving muscle function). It addresses an identified need for better training tools in Paralympic sport. Injuries, especially overuse injuries, remain a significant concern in Paralympic powerlifting. Willick *et al.* [23] documented the injury incidence at the 2012 Paralympics, and while acute injuries (like strains during a lift) were noted, a large share were chronic issues like shoulder and back pain. By implementing equipment like RS, coaches might reduce these chronic issues – for instance, by scheduling regular RS sessions to offload the spine and shoulders while still maintaining training intensity. This could break the cycle of continuous high strain that leads to overuse injuries.

Our findings also resonate with broader research on core stability and athletic performance. Improved trunk stability has been linked to better outcomes in many sports (e.g., throwers, swimmers benefit from core training). For powerlifters, a stable core is essential for maximizing force in bench press, even though it's an upper-body lift. A stable torso provides a solid foundation for the pectorals and deltoids to push against. We observed that RS training increased core muscle activation; over time this can strengthen the lifter's ability to maintain a tight arch and torso rigidity during competition lifts. Thus, training with RS might indirectly increase the raw bench press capability once the athlete transitions back to free lifting, thanks to a stronger stabilizing system. This hypothesis finds some support in analogous studies where instability training improved subsequent performance on stable surfaces by enhancing neuromuscular coordination [19]. Indeed, a systematic review of EMG in bench press by authors [9] noted that exercises which challenge stability can recruit additional musculature, hinting that such practices may benefit maximal force production in the long run. Our study is among the first, to our knowledge, to demonstrate this principle in a Paralympic powerlifting context.

It is also worth discussing the broader applications of the Round Support device beyond the scope of this study. We tested it in bench press scenario primarily focusing on Paralympic lifters, but the RS concept could be applied to other resistance exercises or rehabilitation settings. For instance, athletes recovering from spinal injuries or with limited lower-body function could use RS-assisted exercises to continue training the upper body without fear of exacerbating back problems. The device's adjustable nature means it could be used by individuals with various body sizes and abilities, from recreational gym users to other Paralympic disciplines that require upper-body strength (e.g., wheelchair sports). The compactness and adaptability of the RS (it attaches to standard equipment and is relatively portable) make it a practical addition to gyms or home setups. In this sense, our work introduces a tool that could democratize heavy strength training for those who previously had to avoid it due to back or balance issues. We envision future integration of digital technologies with the RS as well – for example, embedding force sensors or accelerometers to provide real-time feedback on load distribution, symmetry of effort between sides of the body, etc. This could lead to a smart training system that not only aids the lift but also monitors and optimizes it (an idea we plan to explore in subsequent research). Such integration of technology aligns with the modern sports science trend of using sensor data to fine-tune training programs (IoT in sports equipment).

Limitations: While the outcomes are promising, this study has some limitations. The sample size, particularly of Paralympic powerlifters, was limited to 12, which is a small but elite group. Inter-individual differences in impairment might influence how effective the RS is (e.g., an athlete with spinal cord injury vs. an amputee might benefit differently). Our study did not aim to stratify results by impairment type due to sample size, but future research with larger cohorts could examine this. Another limitation is that we did not conduct a long-term trial to directly measure if RS training leads to improvements in raw bench press performance. Our focus was on acute biomechanical and neuromuscular effects. Longitudinal studies are needed to see if e.g. 8 weeks of RS integration yields a higher 1RM or improved competition results compared to conventional training. Furthermore, the RS's load-sharing was fixed in our design (~10–15% assist at bottom). Different levels of assistance might produce different effects, and finding the optimal "assistance curve" (possibly tailored to each athlete) would be a valuable investigation. Finally, while we measured many variables, the complex interplay of reduced load and increased stability could be explored in more detail with advanced musculoskeletal modeling – for example, analyzing joint torques or muscle forces in silico to complement our empirical data.

Practical Implications: Coaches and athletes in Paralympic powerlifting can consider incorporating the Round Support or similar devices into training to reduce injury risk and enhance core engagement. It should be emphasized that RS training is not meant to replace regular bench press training entirely; rather, it's a supplementary method for specific goals (rehabilitation, deload weeks, accessory work, etc.). Athletes might use the RS in certain sessions (for instance, high-volume days or when niggling back pain is present) to allow continued training without exacerbating issues. The increased exercise variety provided by the RS can help maintain progress and motivation. Additionally, the concept of load redistribution demonstrated here could inspire new training equipment designs. For example, spring-loaded bench supports or dynamic spotting machines could emulate some benefits of the RS in a more automated way. Our successful pilot across other sports suggests that any sport requiring upper-body strength and stability (from boxing to wheelchair basketball) could adapt RS exercises to improve core stability and reduce injury risks during strength training.

In conclusion, this study presents a novel evidence-based intervention for the training of elite Paralympic powerlifters. The Round Support multifunctional bar proved effective in lowering spinal compression, enhancing stabilizer muscle activation, and expanding training modalities. These outcomes are aligned with the broader objectives of sports science to improve athlete performance safely and innovatively. Our work contributes to filling the gap in literature regarding specialized training methodologies for athletes with disabilities, demonstrating that targeted engineering solutions can yield substantial benefits. Future research should build on these findings to refine such devices, verify long-term efficacy, and extend the approach to diverse populations. Ultimately, by making strength training safer and more effective, we empower Paralympic athletes to train harder, perform better, and stay healthier – embodying the inclusive and progressive spirit of modern sports.

Conclusions.

Our research gives an efficacy on approach of the Round Support (RS). were observed that the multifunctional barbell significantly reduces spinal compressive forces during bench press exercises by approximately 20%. Such load optimization directly addresses one of the primary injury risks for elite Paralympic powerlifters.

The RS device demonstrates pronounced enhancement of stabilizer muscle activity (approximately 30–35% increased EMG activation) compared to traditional bench presses. Contrary to the expectation that assistive training equipment may decrease muscle engagement, the unique configuration of the RS bar actively stimulates greater involvement of core and deep stabilizer muscles. Over time, regular use of the RS bar thus contributes to improved functional strength, optimized neuromuscular coordination, and superior overall trunk stabilization, crucial for efficient force production and injury prevention.

The versatility and innovative design of the RS bar substantially expand the exercise repertoire for elite athletes, allowing more than 30 different exercise variations beyond traditional bench press movements. This broad range of exercises not only targets primary muscle groups but also effectively engages secondary stabilizers and addresses specific neuromuscular deficiencies, such as muscle asymmetries and strength imbalances.

From an athlete-centered perspective, the RS bar markedly improves perceived lift stability, psychological comfort, and overall confidence during training. Participants reported greater subjective feelings of safety and reduced spinal pressure, resulting in increased training intensity and higher-quality exercise execution. This psychological advantage is crucial for maintaining consistency in maximal strength training, particularly among athletes who may experience chronic discomfort or anxiety due to their impairments. The RS bar thus serves as a practical training innovation that combines biomechanical benefits with significant psychosocial enhancements, empowering Paralympic athletes to train more effectively, safely, and sustainably.

Prospects for further research. Going forward, our work will focus on finding new ways for Paralympic athletes to use the equipment.

Conflict of interest. The authors affirm that they have no conflicts of interest to disclose.

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