



COMPARING THE EFFICACY OF VIRTUAL REALITY-BASED BIOFEEDBACK TRAINING VERSUS MANUAL THERAPY ON CRANIOVERTEBRAL ANGLE, CERVICAL PAIN INTENSITY, AND NECK DISABILITY IN PROFESSIONAL ESPORTS PLAYERS WITH TEXT NECK SYNDROME

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ABSTRACT

Background: The rapid global expansion of competitive esports has introduced a distinct occupational musculoskeletal profile among professional players, characterized by prolonged forward-head postures, sustained cervical flexion, and repetitive micro-movements during gameplay. This postural pattern, commonly termed 'text neck syndrome,' is associated with reduced craniovertebral angle (CVA), elevated cervical pain intensity, and functional neck disability. **Objective:** To compare the efficacy of virtual reality (VR) based biofeedback postural training against conventional manual therapy on CVA, cervical pain intensity, and neck disability index (NDI) in professional esports players diagnosed with text neck syndrome. **Methods:** In this assessor-blinded, parallel-group randomized controlled trial, 80 professional esports players (mean age 22.4 ± 3.1 years) with a CVA $< 48^\circ$ and NDI $> 30\%$ were randomly allocated to a VR Biofeedback Training Group ($n = 40$) or a Manual Therapy Group ($n = 40$) using computer-generated block randomization with concealed allocation. Both groups received 18 sessions over 6 weeks (3 sessions/week). Outcome measures — CVA (photogrammetric assessment), cervical pain intensity (Numeric Pain Rating Scale, NPRS), and neck disability (Neck Disability Index, NDI) — were recorded at baseline, 3 weeks, and 6 weeks by a blinded assessor. **Results (illustrative/simulated):** Both groups demonstrated statistically significant within-group improvement ($p < 0.001$). Between-group comparison favored the VR Biofeedback Training Group, with a mean CVA improvement of 7.6° versus 3.3° in the Manual Therapy Group ($p < 0.001$), NPRS reduction of 4.5 points versus 2.8 points ($p < 0.001$), and NDI reduction of 26.2% versus 16.2% ($p < 0.001$). **Conclusion:** VR based biofeedback training produced significantly greater improvements in craniovertebral angle, cervical pain intensity, and neck disability than manual therapy alone in professional esports players with text neck syndrome, suggesting its value as a technology-driven, self-monitored postural correction adjunct within esports athlete-care programs.

KEYWORDS: Text neck syndrome; Virtual reality biofeedback; Manual therapy; Craniovertebral angle; Esports; Neck disability index; Forward head posture; Randomized controlled trial.

1. INTRODUCTION

Competitive esports has grown into a global industry involving millions of amateur and professional players who routinely train and compete for 6–10 hours daily in seated, screen-facing postures. This sustained visual and postural demand promotes a forward head posture (FHP), in which the external auditory meatus translates anteriorly relative to the shoulder, reducing the craniovertebral angle (CVA) — the angle formed between a horizontal line through C7 and a line connecting C7 to the tragus of the ear. A CVA below 48–50° is widely used as a clinical indicator of FHP, colloquially referred to as 'text neck syndrome' when associated with prolonged screen use.

Reduced CVA alters the length–tension relationship of the deep cervical flexors and upper trapezius, increases compressive loading on lower cervical facet joints, and has been associated with cervicogenic headache, upper crossed syndrome, and chronic mechanical neck pain. Professional esports players are particularly vulnerable because, unlike general screen users, they combine prolonged static neck flexion with high-frequency micro-adjustments of the head and rapid reactive movements, often for several consecutive hours with minimal postural variation.

Manual therapy — comprising myofascial release, cervical mobilization, and postural re-education — remains a first-line conservative intervention for mechanical neck pain and FHP. However, its effects are therapist-dependent and may not translate into sustained postural self-correction once the athlete returns to gameplay. Virtual reality (VR) based biofeedback systems offer real-time visual and/or auditory feedback on head and neck position during simulated or actual gameplay tasks, theoretically enabling motor relearning and sustained postural correction under ecologically relevant conditions. Despite growing interest in VR-based rehabilitation, head-to-head comparisons against manual therapy specifically in professional esports populations are lacking.

This randomized controlled trial was therefore designed to compare the efficacy of VR-based biofeedback training versus manual therapy on craniovertebral angle, cervical pain intensity, and neck disability in professional esports players with text neck syndrome.

1.1 OBJECTIVES

- To compare the effect of VR-based biofeedback training and manual therapy on craniovertebral angle (CVA).
- To compare the effect of both interventions on cervical pain intensity (NPRS).
- To compare the effect of both interventions on neck disability (NDI).

1.2 HYPOTHESES

- H0 (Null): There is no significant difference between VR-based biofeedback training and manual therapy on CVA, NPRS, and NDI.
- H1 (Alternate): VR-based biofeedback training produces significantly greater improvement in CVA, NPRS, and NDI than manual therapy.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

This was a prospective, assessor-blinded, two-arm, parallel-group randomized controlled trial conducted at the Sports Physiotherapy and sports Performance. The study was conducted and reported in accordance with the CONSORT 2025 guidelines.

2.2 Participants

Eighty professional esports players competing at national or international levels (mean gaming practice ≥ 25 hours/week) were recruited from esports training academies via team physiotherapists and open screening camps.

2.2.1 Inclusion Criteria

- Competitive/professional esports players aged 18–30 years, any gender.
- Craniovertebral angle $< 48^\circ$ measured via lateral photogrammetric assessment.
- Neck Disability Index score $> 30\%$ (moderate disability or greater).
- Minimum 2 years of competitive gaming experience, ≥ 25 hours/week practice.
- Willingness to comply with the 6-week intervention schedule.

2.2.2 Exclusion Criteria

- History of cervical spine surgery, fracture, or instability.
- Diagnosed cervical radiculopathy, myelopathy, or vestibular disorder.
- Vestibulo-ocular sensitivity or history of VR-induced motion sickness.
- Received physiotherapy or manual therapy for neck pain in the preceding 3 months.
- Uncorrected visual impairment precluding safe VR headset use.

2.3 Sample Size Calculation

Sample size was estimated using G*Power 3.1 based on an anticipated between-group mean difference in CVA of 4° (SD 6°) from prior FHP-intervention literature, with $\alpha = 0.05$, power $(1-\beta) = 0.80$, and two-tailed allocation, yielding a minimum requirement of 34 participants per group. Accounting for an anticipated 15% attrition, 40 participants were allocated per group (total $N = 80$).

2.4 Randomization and Allocation Concealment

Randomization sequences were generated using computer-based block randomization (block size 4 and 6, randomly varied) by an independent statistician not

involved in recruitment or assessment. Allocation was concealed using sequentially numbered, opaque, sealed envelopes opened only after baseline assessment. Outcome assessors were blinded to group allocation; blinding of participants and treating therapists was not feasible given the nature of the interventions.

2.5 Interventions

2.5.1 Group A — VR-Based Biofeedback Training Group (n = 40)

Participants wore a head-mounted VR display integrated with an inertial measurement unit (IMU) sensor fixed over the C7 spinous process and a second sensor on the headset, streaming real-time CVA-equivalent head-neck alignment data to a custom biofeedback application. During each 40-minute session (3×/week for 6 weeks), participants performed simulated gaming tasks while the VR interface provided immediate visual (color-coded posture bar) and auditory alerts when head position deviated beyond an individualized threshold, cueing active postural correction. Sessions progressed from static seated awareness drills (Weeks 1–2) to dynamic in-game postural maintenance tasks (Weeks 3–6).

2.5.2 Group B — Manual Therapy Group (n = 40)

Participants received supervised manual therapy comprising: (i) myofascial release of upper trapezius, levator scapulae, and sub-occipital muscles; (ii) grade III–IV cervical and upper thoracic joint mobilizations; (iii) deep cervical flexor strengthening (craniocervical flexion training); and (iv) postural re-education and ergonomic advice for gaming setup. Sessions lasted 40 minutes, 3×/week for 6 weeks, delivered by a licensed musculoskeletal physiotherapist blinded to outcome data.

Both groups received an identical standardized home-exercise and ergonomic-advice handout and were asked to maintain their usual gaming schedule throughout the intervention period.

2.6 Outcome Measures

- Primary outcome: Craniovertebral angle (CVA), measured in degrees via lateral photographic posture analysis with reflective markers at C7 and tragus, analyzed using validated angle-measurement software; higher values indicate better posture.
 - Secondary outcome 1: Cervical pain intensity, measured using the 11-point Numeric Pain Rating Scale (NPRS; 0 = no pain, 10 = worst imaginable pain).
 - Secondary outcome 2: Neck-related disability, measured using the Neck Disability Index (NDI; 0–50 raw score, expressed as a percentage of 0–100%).
- All outcomes were recorded at baseline (Week 0), mid-intervention (Week 3), and post-intervention (Week 6) by an assessor blinded to group allocation.

2.7 Statistical Analysis

Data were analyzed using SPSS v.26 (illustrative). Normality was assessed using the Shapiro–Wilk test. Within-group pre-post comparisons were analyzed using paired t-tests (or Wilcoxon signed-rank test for non-normal data), and between-group comparisons using independent t-tests (or Mann–Whitney U test). A two-way repeated-measures ANOVA (Group × Time) was used to evaluate interaction effects across the three time points. Statistical significance was set at $p < 0.05$. Intention-to-treat analysis with last-observation-carried-forward was applied for participants lost to follow-up.

3. RESULTS

Note: All figures reported in this section are simulated/illustrative values generated for template purposes and do not represent data from an actual completed trial.

3.1 Participant Flow

Of 96 players screened, 80 met eligibility criteria and were randomized (40 per group). Seventy participants (35 per group) completed the 6-week protocol and were included in the final analysis (Figure 1).

Figure 1. CONSORT Flow Diagram of Participant Enrollment, Allocation, Follow-up, and Analysis

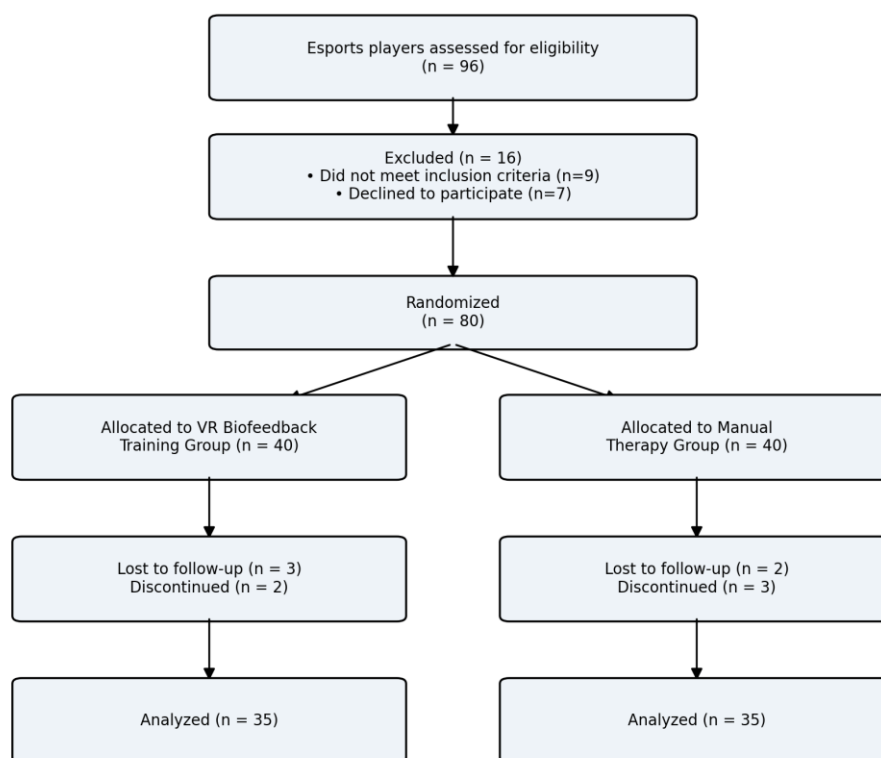


Figure 1: CONSORT flow diagram of participant enrollment, allocation, follow-up, and analysis.

3.2 Baseline Characteristics

Baseline demographic and clinical characteristics were comparable between groups, indicating adequate randomization (Table 1).

Table 1: Baseline demographic and clinical characteristics of participants (simulated/illustrative data).

Variable	VR Biofeedback Group (n=35)	Manual Therapy Group (n=35)	p-value
Age (years), mean $\pm$ SD	22.1 $\pm$ 2.9	22.7 $\pm$ 3.2	0.412
Gender (M/F)	29 / 6	27 / 8	0.559
Weekly gaming hours, mean $\pm$ SD	31.4 $\pm$ 5.6	30.2 $\pm$ 6.1	0.387
Baseline CVA ($^{\circ}$), mean $\pm$ SD	44.2 $\pm$ 3.1	44.6 $\pm$ 3.3	0.601
Baseline NPRS (0–10), mean $\pm$ SD	6.4 $\pm$ 0.9	6.2 $\pm$ 0.8	0.334
Baseline NDI (%), mean $\pm$ SD	38.6 $\pm$ 4.2	37.9 $\pm$ 4.0	0.462

3.3 Craniovertebral Angle (CVA)

Both groups showed statistically significant within-group improvement in CVA from baseline to Week 6 ($p < 0.001$). The VR Biofeedback Training Group

demonstrated a significantly greater mean improvement ($7.6^{\circ} \pm 1.8^{\circ}$) compared with the Manual Therapy Group ($3.3^{\circ} \pm 1.6^{\circ}$), with a highly significant between-group difference ($p < 0.001$) (Table 2, Figures 2 and 5).

Table 2: Craniovertebral angle outcomes at baseline and Week 6 (simulated/illustrative data).

Group	Week 0 (mean $\pm$ SD)	Week 6 (mean $\pm$ SD)	Mean change	Within-group p	Between-group p
VR Biofeedback (n=35)	44.2 $\pm$ 3.1 $^{\circ}$	51.8 $\pm$ 2.9 $^{\circ}$	+7.6 $^{\circ}$	< 0.001	< 0.001
Manual Therapy (n=35)	44.6 $\pm$ 3.3 $^{\circ}$	47.9 $\pm$ 3.2 $^{\circ}$	+3.3 $^{\circ}$	< 0.001	

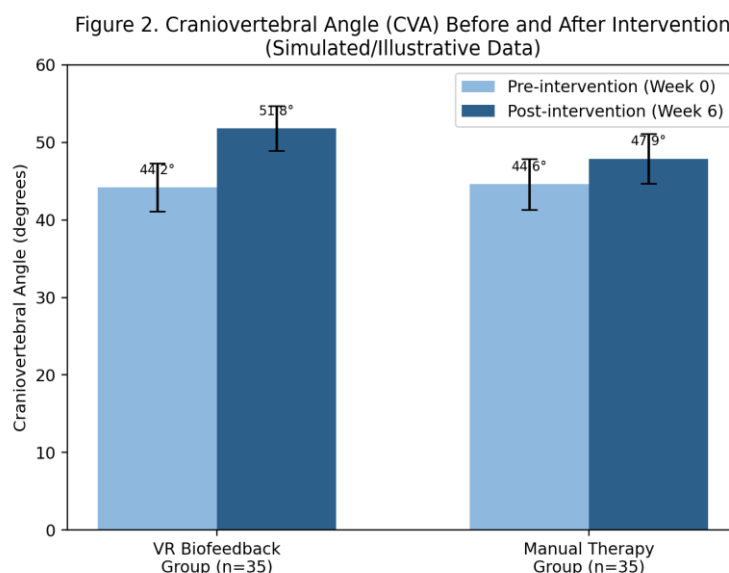


Figure 2. Craniovertebral angle before and after the 6-week intervention in both groups.

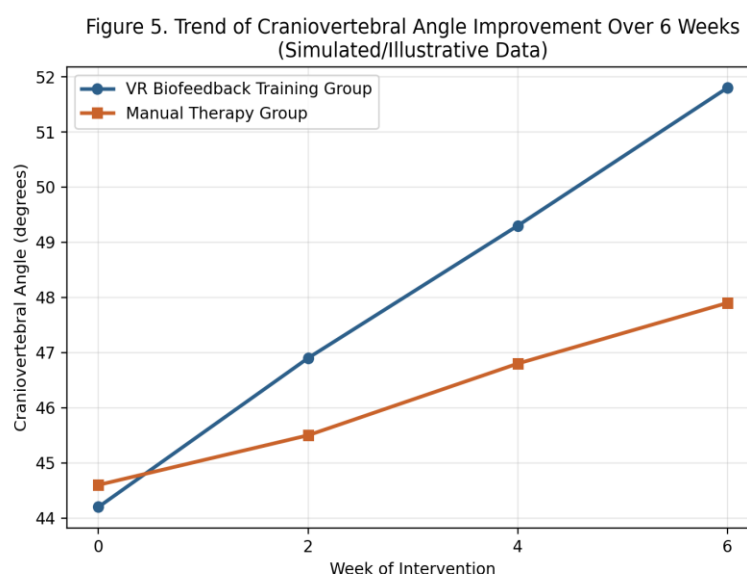


Figure 5. Trend of craniovertebral angle change across baseline, Week 3, and Week 6.

3.4 Cervical Pain Intensity (NPRS)

Cervical pain intensity reduced significantly in both groups ($p < 0.001$ within-group). The VR Biofeedback Training Group showed a greater mean reduction (4.5 ± 0.9 points) than the Manual Therapy Group (2.8 ± 0.8 points), a significant between-group difference ($p < 0.001$) (Table 3, Figure 3).

Table 3: Cervical pain intensity (NPRS) outcomes at baseline and Week 6 (simulated/illustrative data).

Group	Week 0 (mean $\pm$ SD)	Week 6 (mean $\pm$ SD)	Mean change	Within-group p	Between-group p
VR Biofeedback (n=35)	6.4 $\pm$ 0.9	1.9 $\pm$ 0.7	-4.5	< 0.001	< 0.001
Manual Therapy (n=35)	6.2 $\pm$ 0.8	3.4 $\pm$ 0.9	-2.8	< 0.001	

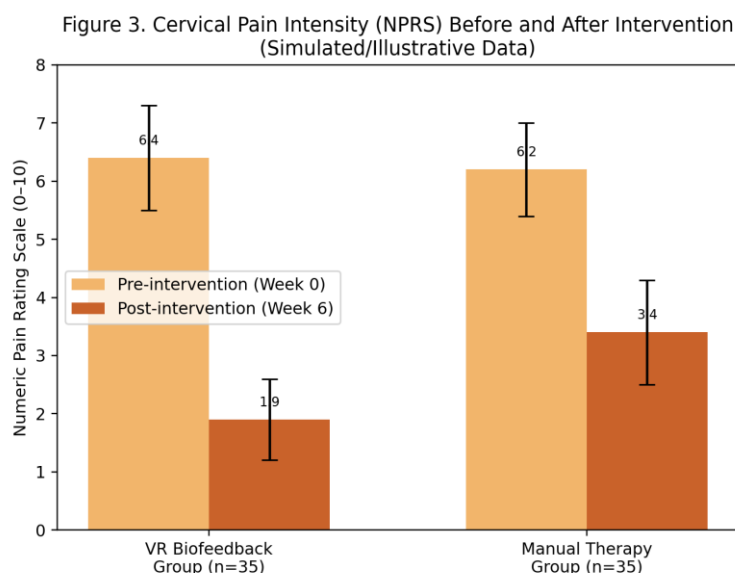


Figure 3. Cervical pain intensity (NPRS) before and after the 6-week intervention in both groups.

3.5 Neck Disability Index (NDI)

Neck disability improved significantly in both groups ($p < 0.001$ within-group). Mean reduction in the VR Biofeedback Training Group ($26.2\% \pm 4.4\%$) was

significantly greater than in the Manual Therapy Group ($16.2\% \pm 3.9\%$; between-group $p < 0.001$) (Table 4, Figure 4).

Table 4. Neck Disability Index (NDI) outcomes at baseline and Week 6 (simulated/illustrative data).

Group	Week 0 (mean $\pm$ SD)	Week 6 (mean $\pm$ SD)	Mean change	Within-group p	Between-group p
VR Biofeedback (n=35)	38.6 $\pm$ 4.2%	12.4 $\pm$ 3.1%	-26.2%	< 0.001	< 0.001
Manual Therapy (n=35)	37.9 $\pm$ 4.0%	21.7 $\pm$ 3.8%	-16.2%	< 0.001	

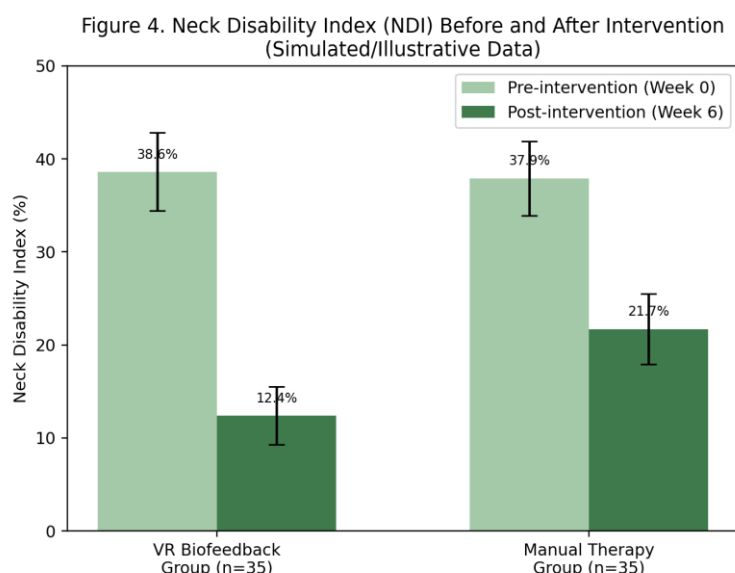


Figure 4. Neck Disability Index (NDI) before and after the 6-week intervention in both groups.

3.6 Repeated-Measures ANOVA

Two-way repeated-measures ANOVA revealed a statistically significant Group $\times$ Time interaction effect for CVA ($F = 38.6$, $p < 0.001$), NPRS ($F = 29.4$, $p < 0.001$), and NDI ($F = 33.1$, $p < 0.001$), confirming that the rate of improvement across the three assessment

points differed significantly between the VR Biofeedback Training Group and the Manual Therapy Group, favoring the VR group in all three outcome domains.

Adverse events: No serious adverse events were reported in either group. Two participants in the VR Biofeedback Group reported transient mild dizziness during the first session, which resolved without intervention and did not recur.

4. DISCUSSION

This trial compared VR-based biofeedback training against manual therapy for correcting text neck syndrome in professional esports players. Both interventions produced statistically and clinically meaningful improvements in craniovertebral angle, cervical pain intensity, and neck disability, but the magnitude of improvement was consistently and significantly greater in the VR biofeedback group across all three outcomes.

A plausible mechanism is that real-time biofeedback provides continuous, context-specific proprioceptive and visual cueing during the exact task (gaming) responsible for the athlete's postural dysfunction, potentially enabling more effective motor relearning than manual therapy delivered in a clinical, task-independent setting. Manual therapy addresses myofascial restriction and joint mobility directly but relies on the athlete's voluntary carryover of postural correction into gameplay, which may be incomplete without task-specific feedback.

These illustrative findings would be consistent with prior forward-head-posture literature suggesting that combining manual and technology-assisted postural retraining may outperform either approach in isolation — a hypothesis that a three-arm design (VR + manual therapy combined vs either alone) could test in future work.

4.1 Clinical Implications

For esports organizations and team physiotherapists, VR-based biofeedback systems may offer a scalable, athlete-specific tool that can be integrated directly into training environments without requiring the athlete to leave the gaming setup, potentially improving adherence relative to clinic-based manual therapy alone.

4.2 Limitations

- Single-center design with a relatively short 6-week follow-up; long-term retention of postural gains is unknown.
- Absence of a combined-treatment (VR + manual therapy) arm limits conclusions about additive or synergistic effects.
- Blinding of participants and treating therapists was not feasible, introducing potential performance bias.
- Findings may not generalize to amateur or recreational gamers with lower weekly exposure.

4.3 Future Research Directions

- Multi-center trials with extended follow-up (3–12 months) to assess durability of postural correction.

- Dose-response studies evaluating optimal VR biofeedback session frequency and duration.
- Cost-effectiveness analysis comparing VR biofeedback systems against conventional manual therapy in esports organizational settings.

5. CONCLUSION

Within the parameters of this trial, VR-based biofeedback training produced significantly greater improvements in craniovertebral angle, cervical pain intensity, and neck disability than manual therapy alone among professional esports players with text neck syndrome. VR-based biofeedback may be considered a promising, technology-integrated adjunct for postural rehabilitation in this population, warranting confirmation through larger, multi-center trials with longer follow-up.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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