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Acute effects of fencing-related physical effort on dynamic visual acuity and response time in fencers: a virtual-reality assessment

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Abstract

Purpose

To examine the acute effects of a standardised fencing bout on dynamic visual acuity (DVA) and response time in fencers, and to evaluate recovery after five minutes of rest.

Methods

Twenty-nine fencers (mean age 16.4 ± 4.3 years; 76% male) completed optometric screening and DVA/response-time assessments on a virtual-reality system presenting moving Snellen E optotypes at velocities of 5–40 km·h⁻¹. Testing occurred at baseline, immediately after a fencing bout (approximately 3 min to 5 touches at maximal intensity), and after 5 min of seated recovery. Heart rate was recorded concurrently. Data were analysed with Wilcoxon signed-rank tests and Holm–Bonferroni correction ($\alpha = 0.05$).

Results

Heart rate increased from a median of 76 beats·min⁻¹ at baseline to 122 beats·min⁻¹ post-effort and remained elevated at 96 beats·min⁻¹ after recovery (all $p < 0.001$). DVA declined after the bout at several intermediate and high velocities; recovery was complete at some speeds and incomplete at others. Response time lengthened after effort and remained above baseline after recovery at several velocities.

Conclusions

Acute fencing-related physical effort is associated with reductions in DVA and, more persistently, in response speed, particularly at higher stimulus velocities. Five minutes of rest partially restores visual resolution but not visuomotor speed or heart rate. Assessing sports-vision performance under conditions of recent physical effort may provide additional insight for performance evaluation in fencing.

Key Points

A brief high-intensity fencing bout produces velocity-dependent reductions in dynamic visual acuity, with incomplete recovery at some higher speeds after five minutes.

Response time remains elevated after short recovery more persistently than DVA, suggesting different recovery time courses for visual resolution and visuomotor speed.

Sports-vision assessment performed only under rested conditions may underestimate the visual and visuomotor limitations that appear shortly after intense physical effort in fencing.

Introduction

Fencing is a high-speed combat sport that requires continuous identification of relevant visual information, anticipation of an opponent's actions, and execution of precise motor responses within extremely short time windows (Vincze et al., 2026; Laby & Appelbaum, 2021). Performance therefore depends not only on technical and tactical skill but also on the capacity to process moving visual stimuli while maintaining rapid visuomotor control.

Dynamic visual acuity (DVA)—the ability to resolve detail when the stimulus, the observer, or both are in motion—is particularly relevant for sports involving interception and rapid target displacement. Athletes frequently demonstrate superior DVA relative to non-athletes (Gao et al., 2015; Yee et al., 2021). In fencing these visual demands are tightly integrated with weapon control, spatial attention and rapid decision-making (Ceyte et al., 2017; Palidis et al., 2017; Varesco et al., 2024).

Virtual-reality (VR) systems allow standardised assessment of DVA by precisely controlling stimulus velocity, direction and testing conditions (Waisberg et al., 2022; Hirano et al., 2017). Acute physical effort can alter visual function through changes in physiological activation, attentional state and oculomotor control (Shaw et al., 2025; Connell et al., 2017; Patterson et al., 2017). Evidence specifically addressing the immediate effect of fencing-related physical effort on DVA and response time is scarce.

The present study examined the acute effect of a standardised fencing bout on DVA and response time in fencers and evaluated whether a five-minute recovery period restores these variables to baseline. We hypothesised that fencing-related physical effort would reduce DVA and lengthen response time, particularly at higher stimulus velocities, and that recovery after five minutes would be only partial.

Methods

Participants

This prospective repeated-measures experimental study recruited fencers from Sala de Armas de Madrid. Of 40 athletes initially assessed, 29 met eligibility criteria and completed the protocol (mean age 16.38 ± 4.28 years; 76% male). Most were right-handed (72%). Mean weekly training volume was 468.62 ± 243.51 min. Weapon distribution was 66% foil, 17% épée and 17% sabre.

Inclusion criteria comprised monocular static visual acuity ≥ 0.8 (decimal), age ≥ 7 years, voluntary participation and signed informed consent (or parental consent for minors). Exclusion criteria were strabismus or phoria > 20 prism diopters, inability to understand the protocol, and systemic disease. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Universidad Complutense de Madrid (code 25/698-E). Written informed consent was obtained from all participants or their legal guardians.

Sample size estimation and justification

No formal a priori sample-size calculation was performed because recruitment was constrained by the finite number of eligible fencers available. A post-hoc sensitivity analysis (G*Power 3.1) indicated that with n = 29, α = 0.05 and power = 0.80 the minimum detectable effect size (Cohen's dz) for a Wilcoxon signed-rank test is approximately 0.55 (medium effect).

Optometric screening

Participants underwent a standardised optometric examination (monocular static visual acuity, retinoscopy, near and induced phoria, accommodative facility and AC/A ratio). Most required no correction (72%). Mean spherical equivalent was − 0.22 ± 0.47 D (right eye) and − 0.14 ± 0.79 D (left eye). Binocular static visual acuity was 1.0 ± 0.0.

Experimental design and procedures

Each participant was tested at three time points: baseline, immediately after a fencing bout, and after five minutes of seated recovery. Primary outcomes were DVA and response time; heart rate served as a physiological marker of cardiovascular response.

The fencing bout consisted of a continuous exchange lasting approximately three minutes or until five touches were scored, performed at maximal intensity with the athlete's usual weapon. Immediately after the bout, participants walked to the testing area (≈ 10–15 s) and the post-effort assessment began. The recovery period was five minutes of quiet seated rest.

DVA and response time were measured with a head-mounted virtual-reality system presenting moving Snellen E optotypes at eight controlled velocities (5, 10, 15, 20, 25, 30, 35 or 40 $km \cdot h^{-1}$) in randomly selected directions. Participants identified the orientation of the E via a handheld controller. DVA was recorded as the smallest correctly identified optotype size (decimal); response time was the interval (ms) from stimulus onset to button press. Two familiarisation trials (up to 20 $km \cdot h^{-1}$) were excluded from analysis. The experimental sequence progressed from 5 to 40 $km \cdot h^{-1}$. A fixed ascending order of velocities was used for practical reasons and to maintain a consistent testing protocol across participants; this design does not fully exclude possible order or cumulative fatigue effects within the visual assessment block. This limitation is acknowledged and discussed.

Heart rate alone does not establish the presence or magnitude of neuromuscular or perceptual fatigue; no ratings of perceived exertion were collected. Changes are therefore interpreted in relation to acute physical effort rather than confirmed exercise-induced fatigue.

Statistical analysis

Distributions were non-normal (Shapiro–Wilk). Results are reported as medians. Pairwise Wilcoxon signed-rank tests compared baseline with post-effort and baseline with recovery at each velocity (α = 0.05, two-tailed). Holm–Bonferroni correction was applied. Effect sizes are described qualitatively using rank-biserial correlation thresholds. Occasional response times > 10 s were retained; sensitivity analyses excluding times > 8 s did not alter the pattern of results. Analyses were performed in Jamovi (v. 2.6.45).

Results

Participant characteristics

Baseline heart rate was 77.17 ± 10.20 beats·min⁻¹, mean baseline DVA 0.90 ± 0.05, and mean baseline response time 3915.52 ± 640.33 ms (Table 1).

Table 1
Participant and optometric characteristics (n = 29)

Variable	Value
Age (yr)	16.38 ± 4.28
Sex	76% male; 24% female
Dominant hand	72% right; 28% left
Weekly training (min·wk⁻¹)	468.62 ± 243.51
Weapon	66% foil; 17% épée; 17% sabre
Optical correction	None 72%; spectacles 21%; CL 7%
Binocular static VA	1.0 ± 0.0
Baseline heart rate (beats·min⁻¹)	77.17 ± 10.20
Baseline DVA	0.90 ± 0.05
Baseline response time (ms)	3915.52 ± 640.33

Values are mean ± SD or percentage. VA = visual acuity; CL = contact lenses; DVA = dynamic visual acuity.

Dynamic visual acuity

DVA showed a velocity-dependent response (Table 2 and Fig. 1). At 5 and 10 km·h⁻¹ values remained stable. At 15, 20 and 40 km·h⁻¹, DVA declined after the bout and recovered fully after five minutes. At 30 and 35 km·h⁻¹ recovery was incomplete (baseline vs recovery remained significant after Holm–Bonferroni correction).

Table 2
Median dynamic visual acuity (decimal) at baseline, post-effort and recovery

Velocity (km·h⁻¹)	Baseline	Post-effort	Recovery	Main pattern
5	0.9	0.9	0.9	Stable
10	0.9	0.9	0.9	Stable
15	1.0	0.9	1.0	Decline → full recovery
20	0.9	0.8	0.9	Decline → full recovery
25	0.8	0.8	0.9	Recovery ≥ baseline (n.s.)
30	0.9	0.7	0.8	Decline → incomplete recovery*
35	0.9	0.7	0.8	Decline → incomplete recovery*
40	0.8	0.7	0.8	Decline → full recovery

** Baseline versus recovery remained significant after Holm–Bonferroni correction.*

Heart rate

Median heart rate increased from 76 beats·min⁻¹ at baseline to 122 beats·min⁻¹ post-effort and declined only partially to 96 beats·min⁻¹ after recovery (all pairwise comparisons $p < 0.001$) (Table 3 and Fig. 3).

Table 3
Median heart rate (beats·min⁻¹)

Baseline	Post-effort	Recovery	Interpretation
76	122	96	Marked increase; incomplete recovery

Response time

Response time increased after the bout at most intermediate and high velocities and remained elevated relative to baseline after recovery at 20, 25, 30, 35 and 40 km·h⁻¹ (Table 4 and Fig. 2). Occasional response times exceeding 10 s (mainly post-effort) were retained; sensitivity analyses did not change the overall pattern.

Table 4
Median response time (ms) at baseline, post-effort and recovery

Velocity (km·h⁻¹)	Baseline	Post-effort	Recovery	Main pattern
5	4150	4100	4200	Minor fluctuations
10	1850	2256	2100	Increase → partial recovery
15	3900	4790	3850	Increase → recovery ≤ baseline
20	2800	4150	2900	Increase → remains above baseline*
25	3450	3540	3600	Increase → remains elevated*
30	2100	2200	2200	Increase → no recovery*
35	2150	2200	2200	Increase → no recovery*
40	1750	2500	1850	Increase → partial recovery*

** Residual elevation remained significant or near-significant after Holm–Bonferroni correction.*

Discussion

The principal finding is that a brief, high-intensity fencing bout is associated with velocity-dependent reductions in DVA and, more persistently, in response time. These results support the hypothesis that acute physical effort related to fencing can affect visual and visuomotor performance, especially under higher stimulus velocities.

At low velocities DVA remained relatively stable. Intermediate-to-high velocities produced clear post-effort decrements. Full recovery of DVA within five minutes at some speeds indicates that certain aspects of dynamic visual resolution can rebound rapidly, whereas incomplete recovery at 30 and 35 km·h⁻¹ suggests that combined demands of detection, tracking and response preparation can exceed short-term recovery capacity.

Response time was more persistently affected. Elevated values after recovery at five of the eight velocities indicate that visuomotor processing is more vulnerable to residual effects of physical effort than pure visual resolution.

Heart-rate data confirmed a substantial cardiovascular response and incomplete recovery after five minutes. The dissociation between partial DVA recovery and persistent response-time elevation suggests different recovery time courses for visual resolution and visuomotor speed.

From an applied perspective, the findings support assessing sports-vision performance under conditions of recent physical effort. Testing solely under rested conditions may underestimate limitations that appear shortly after intense exchange.

Limitations

Several limitations should be acknowledged. The fixed ascending order of stimulus velocities does not fully exclude possible order, learning or cumulative fatigue effects within the visual assessment block; future work should randomise velocity order. Measurements were obtained immediately after rather than during the bout. Heart rate confirms cardiovascular demand but does not quantify neuromuscular or perceptual fatigue. The sample was relatively small and predominantly adolescent, and no pure rest-control condition was included. These factors limit generalisability.

Conclusions

A brief, high-intensity fencing bout is associated with reductions in dynamic visual acuity and, more persistently, in response time, particularly at intermediate and high stimulus velocities. Five minutes of recovery partially restores visual resolution but not response time or heart rate. These results support the value of evaluating sports-vision performance under conditions of recent physical effort.

Declarations

Disclosure statement

The authors report there are no competing interests to declare.

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Author Contribution

Conceptualization: A.D.O., M.J.E., J.E.C.-S., R.G.-J., F.J.P.-M. and R.B.V.; methodology, formal analysis, investigation, data curation and writing—original draft: A.D.O. and M.J.E.; writing—review and editing: J.E.C.-S., R.G.-J., F.J.P.-M. and R.B.V.; supervision: R.B.V. All authors approved the final manuscript.

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Data Availability

https://doi.org/10.6084/m9.figshare.34980991

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Figures

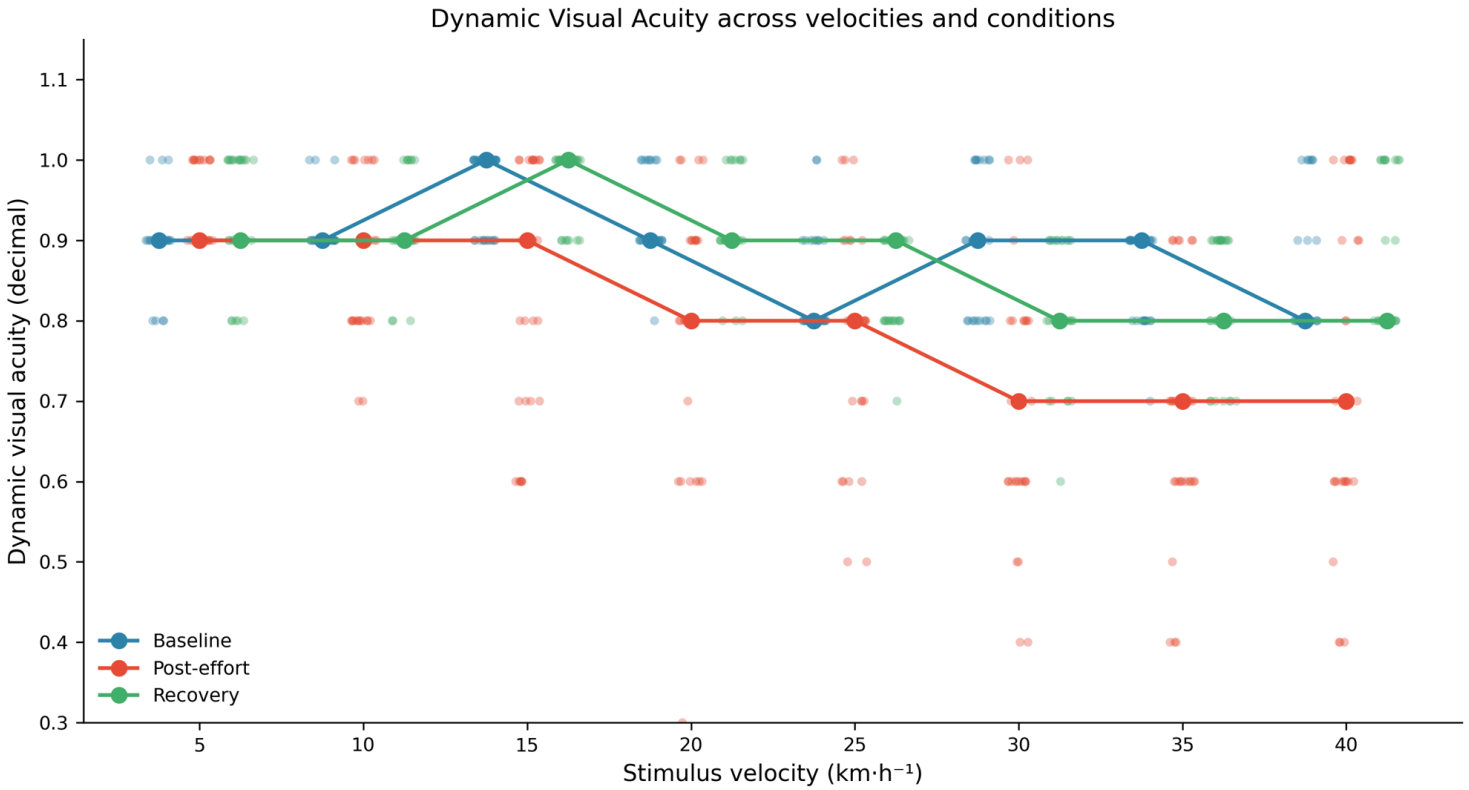


Figure 1

Dynamic visual acuity (decimal) across stimulus velocities at baseline, post-effort and recovery. Individual data points are shown together with median values connected by lines.

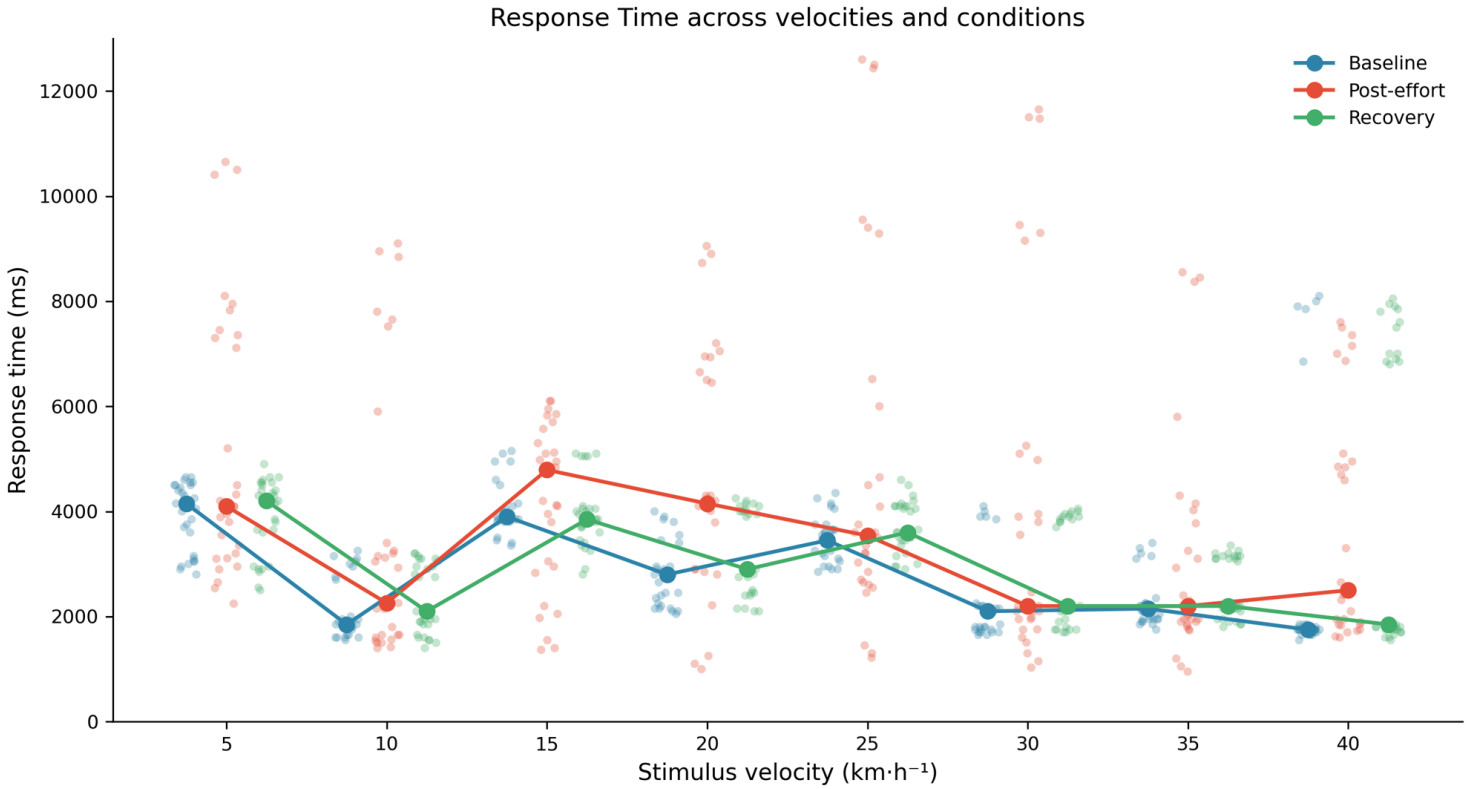


Figure 2

Response time (ms) across stimulus velocities at baseline, post-effort and recovery. Individual data points are shown together with median values connected by lines.

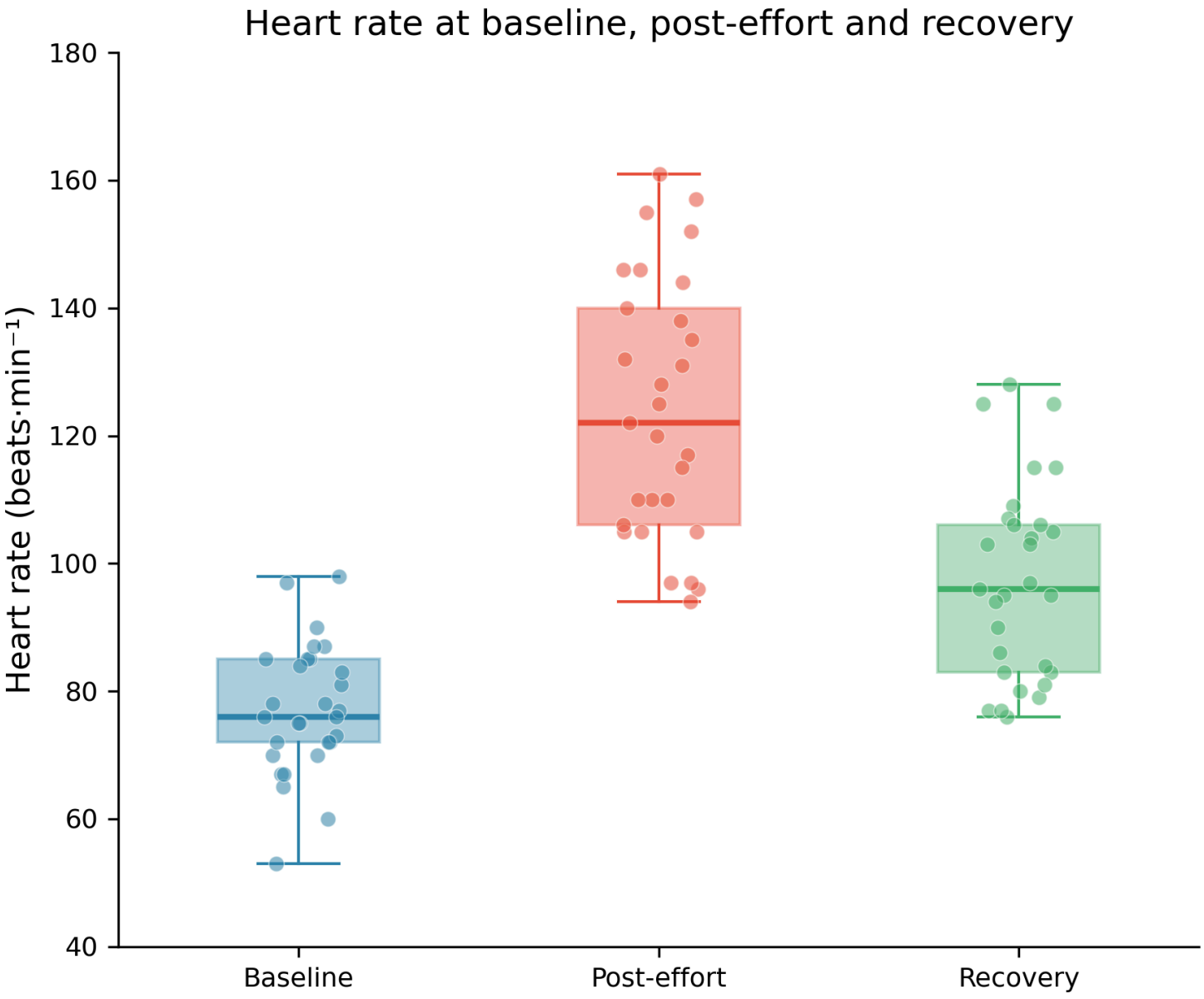


Figure 3

Heart rate (beats·min⁻¹) at baseline, immediately after the fencing bout and after 5 min recovery. Box plots show median, interquartile range and range; individual data points are overlaid.