

The extra-time artefact: Exposure duration, not knockout status, accounts for higher accumulated running distance at the 2026 World Cup

 **Danail Ivanov**  . Department of Football and Tennis. National Sports Academy "Vasil Levski". Sofia, Bulgaria.
 **Grigor Gutev**. Department of Football and Tennis. National Sports Academy "Vasil Levski". Sofia, Bulgaria.
 **Iva Dimova**. Department of Football and Tennis. National Sports Academy "Vasil Levski". Sofia, Bulgaria.

ABSTRACT

Total distance is often reported to be higher in the knockout than in the group phase of football tournaments, but accumulated distance can be compared only across equal exposure. This study examined whether the knockout excess at the 2026 World Cup reflected tournament phase or extra-time. Team-match tracking data (104 matches, 48 teams, 208 observations; 18 with extra-time) were analysed with linear mixed models including crossed random intercepts for match and team. Unadjusted, knockout matches showed 8.52 km more total distance (95% CI 4.73 to 12.30; $p < .001$). After adjustment for extra-time, the knockout coefficient was -0.52 km (-2.38 to 1.34 ; $p = .584$), extra-time accounted for 32.31 km, and marginal R^2 rose from .145 to .764. Knockout matches of 90 minutes did not differ from group matches in total, high-speed or sprint output. Extra-time accrued total distance at 86% of the regulation rate but distance above 20 km/h at only 34%. Per-90 phase comparisons were sensitive to exposure errors of one to three minutes. Running above 7 km/h did not distinguish winners from losers. The knockout increase in accumulated distance reflects unequal exposure; volume, work rate and peak intensity require different denominators.

Keywords: performance analysis; soccer; external load; time-motion analysis; mixed-effects models; normalisation.

Cite this article as:

Ivanov, D., Gutev, G., & Dimova, I. (2027). The extra-time artefact: Exposure duration, not knockout status, accounts for higher accumulated running distance at the 2026 World Cup. *Journal of Human Sport and Exercise*, 22(1), 148-162. <https://doi.org/10.55860/ecgwv395>

 **Corresponding author.** National Sports Academy "Vasil Levski", Department of Football and Tennis, Sofia 1700, Bulgaria.

E-mail: danail.ivanov@nsa.bg

Submitted for publication July 22, 2026.

Accepted for publication September 21, 2026.

Published October 08, 2026.

[Journal of Human Sport and Exercise](#). ISSN 1988-5202.

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doi: <https://doi.org/10.55860/ecgwv395>

INTRODUCTION

Total distance covered remains the most widely reported locomotor variable in applied and research settings in football, and it is routinely used to compare matches, teams, competitions and phases of play (Carling, 2013; Chmura et al., 2018). In tournament football a recurrent observation is that teams appear to cover more distance in the knockout phase than in the group phase, and this pattern is often read as evidence that elimination fixtures impose a heavier physical load. The interpretation matters in practice, because it informs rotation, tapering and recovery decisions for the most decisive fixtures of a competition.

Any such comparison rests on a measurement principle that is easy to state and easy to overlook: an accumulated quantity scales with the time over which it is accumulated. Total distance is a measure of volume. It answers the question of how much locomotor work was performed, not how hard that work was per unit of time, and it does not describe the intensity of the most demanding periods of play. The external-load framework distinguishes what an athlete does from how the athlete responds to it (Impellizzeri et al., 2019), but within external load itself at least three constructs should be kept apart: accumulated volume, relative work rate (volume per unit of exposure) and peak or competitive intensity (Figure 1). Observations that differ in exposure time can be compared on volume only when the question concerns total burden; when the question concerns demand, an appropriate denominator is required. The principle is general. It applies to substitutes compared with starters, to matches with different amounts of added time, to competition formats with and without extra periods, and to any sport in which match duration is variable.

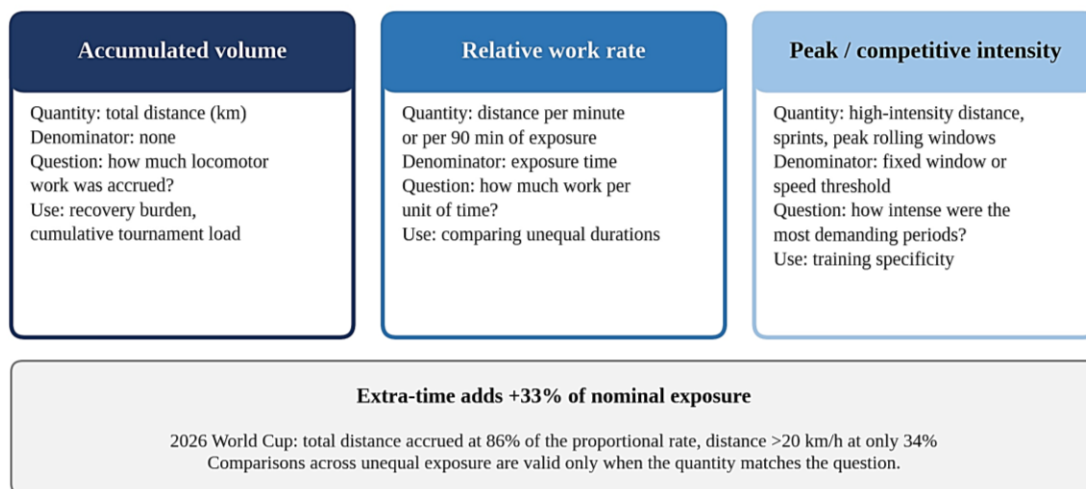


Figure 1. Conceptual framework distinguishing accumulated volume, relative work rate and peak intensity, with the denominator and practical question appropriate to each.

Tournament football provides an unusually clear case. Group-phase matches are contested over 90 minutes of regulation play, whereas knockout matches level after regulation proceed to 30 minutes of extra-time. A substantial proportion of knockout fixtures reach extra-time: roughly one in three World Cup knockout matches between 1986 and 2014, and half of the knockout matches at the 2014 tournament (Eliakim et al., 2020; Kubayi & Toriola, 2018). Because extended matches occur only in the knockout phase, a raw comparison of accumulated distance between phases confounds tournament phase with exposure duration.

The extra-time literature also indicates that the additional period is not played at regulation intensity. A systematic review reported that players cover 5–12% less distance relative to time during extra-time than

during the preceding 90 minutes (Field et al., 2022). Studies of the 2014 World Cup, the 2016 European Championship and controlled 120-minute protocols show declines in relative running output, high-intensity running, top speed and sprint counts during the extra period (Kubayi & Toriola, 2018; Lago-Peñas et al., 2015; Mohr et al., 2023), and matches with extra-time have been followed by altered running output in subsequent fixtures (Kołodziejczyk et al., 2021; Wei et al., 2025). If extra-time adds volume at reduced intensity, a phase difference in accumulated distance could arise without any difference in how teams perform per unit of time, and different locomotor variables would be expected to respond differently.

Match running output is, moreover, shaped by contextual factors such as score-line, opponent and the tactical situation (Bradley & Noakes, 2013; Paul et al., 2015), and its relationship with competitive success is weak relative to technical-tactical indicators (Andrzejewski et al., 2022; Aquino et al., 2021; Barthelemy et al., 2024; Chmura et al., 2022; Modric et al., 2023; Oliva-Lozano et al., 2023). Analyses of running and outcome must therefore respect two structural features of match data: the two teams in a match share the same match conditions, and the competitive outcome must be defined in a way that is comparable across phases.

The present study used team-level tracking data from the 2026 World Cup to examine whether the knockout-phase excess in accumulated total distance persists after the additional exposure of extra-time is taken into account. It was hypothesised that the knockout coefficient would be substantially attenuated, and rendered non-significant, once extra-time was modelled. Secondary aims were to examine whether the pattern holds across speed zones, to quantify how extra-time accrues output relative to regulation play, and to test whether duration-normalised running output distinguishes winners from losers within the same match.

MATERIAL AND METHODS

Participants and data source

This was a retrospective observational study of team-match observations from the 2026 World Cup (48 teams, 104 matches). Physical performance data were obtained from the official match physical data released for the competition, generated by the tournament's multi-camera optical tracking system (Hawk-Eye Innovations). The unit of analysis was the team-match: each match contributed two observations, one per team, giving 208 observations. Of these, 144 belonged to the group phase and 64 to the knockout phase (round of 32, $n = 32$; round of 16, $n = 16$; quarter-finals, $n = 8$; semi-finals, $n = 4$; third-place match, $n = 2$; final, $n = 2$). Eighteen observations (nine matches) reached extra-time; five of these matches were decided in extra-time and four by penalties. Teams contributed between three and eight matches ($M = 4.33$).

Measures

Team values were computed as the sum over all players who took part in the match for that team, including goalkeepers and substitutes; this aggregation was verified by reconstructing each of the 208 team totals from the player-level records. The primary dependent variable was total distance (km). Secondary locomotor variables were distance in five speed zones (0–7, 7–15, 15–20, 20–25 and >25 km/h), from which distance above 20 km/h (high-intensity distance) and above 25 km/h (sprint distance) were derived; the number of high-speed runs (15–20 km/h) and sprints (>20 km/h), that is, counts of discrete running efforts in those speed bands as defined and delivered by the tracking provider and not derived from raw positional data in this study; the highest top speed recorded by any player of the team (peak top speed); and the mean of players' individual top speeds (mean player top speed). Team labels were harmonised before analysis so that each of the 48 teams had a single identifier. Because team values are sums across all players of a team, the two count variables are team totals rather than per-player values, and their magnitude follows from the 13–17 players ($M = 15.8$) contributing to each team-match observation. These variables were audited against

the player-level records (Table 1). Among players with at least 60 min, high-speed runs averaged 80.1 ± 45.6 per match (87.8 ± 48.7 per 90 min; median 94; 5th–95th percentile 9–164; goalkeepers 9.6, defenders 89.2, midfielders 110.3, forwards 80.4 per 90 min) and sprints averaged 28.2 ± 16.4 per match (31.0 ± 17.9 per 90 min; 5th–95th percentile 2–59). Dividing zone distance by the corresponding count gave 11.74 ± 1.09 m per high-speed run and 17.73 ± 3.13 m per sprint in outfield players, implying effort durations of approximately 2.4 and 2.8 s at the midpoint speed of each zone, which is consistent with discrete efforts rather than time samples or frames. Every team total was reproduced exactly by summing the player records, and no player appeared twice within a team-match (0 duplicates among 3,289 player-match records).

Table 1. Audit of the event-count variables: player-level distributions, internal consistency and aggregation check.

Quantity	Mean $\pm$ SD	Median	5 th –95 th percentile	Range / implied effort duration
Player-level distribution (players with ≥ 60 min; n = 2879)				
High-speed runs per match (n)	81.6 ± 47.5	86	9–158	0–252
High-speed runs per 90 min (n)	87.8 ± 48.7	94	9–164	0–229
Sprints per match (n)	28.7 ± 17.1	29	2–56	0–95
Sprints per 90 min (n)	31.0 ± 17.9	32	2–59	0–96
Mean per 90 min by position				
High-speed runs (n)	DF 89.2	MF 110.3	FW 80.4	GK 9.6
Sprints (n)	DF 31.7	MF 35.0	FW 33.3	GK 1.9
Internal consistency: distance accrued per recorded event (outfield players)				
Metres per high-speed run (15–20 km/h distance / count)	11.74 ± 1.09	11.65	10.3–13.5	≈ 2.4 s at 17.5 km/h
Metres per sprint (>20 km/h distance / count)	17.73 ± 3.13	17.44	13.5–22.8	≈ 2.8 s at 22.5 km/h
Aggregation check (208 team-match observations)				
Players contributing per team-match (n)	15.8 ± 0.7	16	13–17	—
Team total minus sum of player records	0 (exact) for both count variables	—	—	—
Duplicate player records within a team-match	0 of 3289 player-match records	—	—	—
Team totals per match: high-speed runs / sprints	$1265.4 \pm 153.9 / 446.2 \pm 57.9$	1272 / 447	—	—

Note. High-speed runs are efforts in the 15–20 km/h zone and sprints are efforts above 20 km/h, as defined and delivered by the tracking provider; they were not derived from raw positional data in this study. Player-level statistics use players with at least 60 min of playing time. Metres per event were computed for outfield players with at least one recorded event; implied durations assume the midpoint speed of the corresponding zone and are consistent with discrete running efforts rather than time samples. Team totals were reconstructed from the player-level records for all 208 team-match observations and matched exactly, and no player appeared twice within a team-match.

Knockout status (0 = group phase, 1 = knockout phase) and extra-time (0 = match completed in regulation, 1 = match extended to 120 minutes) were coded from the match record. Contextual covariates were the absolute final goal margin, the total number of goals in the match, the team's ordinal match number in the tournament, and the opponent's final tournament stage as a proxy for opponent quality. The competitive outcome was the official result (win, draw or loss); in line with competition regulations, matches settled by penalties were classified as draws.

Procedures

Relative (per-90) variables were calculated as the accumulated value multiplied by 90 and divided by the nominal match duration (90 or 120 minutes). The data release does not contain effective playing time or added time, so nominal durations are an approximation of true exposure. Because the approximation could bias per-90 comparisons if added time differed between phases, its consequences were examined in a dedicated sensitivity analysis (see Analysis). The primary adjustment model does not use a minute denominator and is therefore not affected by this approximation. Top-speed variables do not accumulate with time and were not normalised.

Analysis

The data are cross-classified: every match contributes two non-independent observations and every team appears repeatedly. All inferential models were therefore linear mixed models with crossed random intercepts for match (104 levels) and team (48 levels), estimated by maximum likelihood. Intraclass correlation coefficients (ICC) for match and team were obtained from null models. For the primary analysis, Model 1 regressed total distance on knockout status; Model 2 added the extra-time indicator. For each fixed effect, the unstandardised coefficient (B) with 95% confidence interval (CI), exact p -value and standardised coefficient ($\beta = B \times SDx/SDy$) are reported. Explained variance is reported as marginal (fixed effects) and conditional (fixed plus random effects) R^2 (Nakagawa & Schielzeth, 2013). The contribution of extra-time was tested with a likelihood-ratio test of the nested models, and the increment in marginal R^2 (ΔR^2_m) is reported with a 95% CI from 1,000 parametric bootstrap replicates generated from Model 2. As a robustness check, both models were re-estimated by ordinary least squares with two-way cluster-robust standard errors (match and team). The raw between-phase difference is also described by Cohen's d .

Two convergent analyses examined time-adjusted output. First, per-90 total distance was modelled on knockout status. Second, a duration-matched analysis restricted the sample to matches completed in 90 minutes (group phase versus knockout matches without extra-time, $n = 190$), first unadjusted and then adjusted for the contextual covariates; multicollinearity was checked with variance inflation factors. The primary and convergent models were repeated for the ten locomotor variables, with Holm (1979) correction applied within each family of tests. To describe how extra-time accrues output, an accrual ratio was calculated for each volume variable as the extra-time coefficient from Model 2 divided by one third of the regulation group-phase mean; a value of 1.0 indicates that the additional 30 minutes accrued the variable at the regulation rate.

Sensitivity to the exposure approximation was examined in three ways: (a) a deterministic tipping-point analysis in which a common added-time differential between -10 and $+10$ minutes was applied to all knockout matches and the per-90 model re-estimated; (b) a Monte Carlo analysis (1,000 replicates) in which regulation added time was drawn per match from a uniform distribution between 4 and 12 minutes and extra-time added time from a uniform distribution between 1 and 4 minutes, identically for both teams in a match; and (c) two differential Monte Carlo scenarios in which knockout matches received three minutes more or three minutes less added time than group matches. The added-time ranges are assumptions chosen to bracket plausible values, not observed data.

The competitive-outcome analysis used a within-match paired design, which removes shared match conditions and is valid in both phases. In the 80 matches with a winner (52 group, 28 knockout), duration-normalised variables were compared between winning and losing teams with paired t -tests; mean differences with 95% CI and d_z (mean difference divided by the standard deviation of differences) are reported, with Holm correction across variables and phase-stratified effect sizes. Across all 104 matches, including draws, Pearson correlations (with Fisher 95% CI) were computed between the within-match difference in each running variable and the within-match goal difference. The significance level was set at $\alpha = .05$. Analyses were performed in Python 3 with pandas, SciPy and statsmodels (Seabold & Perktold, 2010).

RESULTS

Descriptive statistics and data structure

Across the 208 observations, mean total distance was 114.85 ± 10.29 km (range 90.75–160.49 km). Group-phase observations averaged 112.13 ± 5.00 km and knockout observations 120.97 ± 15.36 km (Cohen's d

= 0.93). The larger dispersion in the knockout phase reflected extended matches: knockout matches completed in 90 minutes averaged 111.98 ± 4.47 km, whereas extra-time observations averaged 143.96 ± 6.53 km (Table 2; Figure 2A). In the null model of accumulated total distance, the ICC was .890 for match and .070 for team; for per-90 total distance the corresponding values were .540 and .291. Observations were therefore strongly clustered, and for accumulated distance most of the match-level variance reflected shared duration.

Table 2. Descriptive statistics of team match running output by match category (mean $\pm$ SD).

Variable	Group phase, 90 min (n = 144)	Knockout, 90 min (n = 46)	Knockout, 120 min (n = 18)	All (N = 208)
Total distance (km) — accumulated	112.13 $\pm$ 5.00	111.98 $\pm$ 4.47	143.96 $\pm$ 6.53	114.85 $\pm$ 10.29
Total distance (km) — per 90 min	112.13 $\pm$ 5.00	111.98 $\pm$ 4.47	107.97 $\pm$ 4.90	111.74 $\pm$ 5.00
Distance 0–7 km/h (km) — accumulated	43.63 $\pm$ 1.79	45.25 $\pm$ 2.23	59.86 $\pm$ 2.89	45.40 $\pm$ 4.93
Distance 0–7 km/h (km) — per 90 min	43.63 $\pm$ 1.79	45.25 $\pm$ 2.23	44.89 $\pm$ 2.17	44.10 $\pm$ 2.05
Distance 7–15 km/h (km) — accumulated	46.14 $\pm$ 3.26	44.69 $\pm$ 3.58	58.33 $\pm$ 5.17	46.87 $\pm$ 5.02
Distance 7–15 km/h (km) — per 90 min	46.14 $\pm$ 3.26	44.69 $\pm$ 3.58	43.75 $\pm$ 3.88	45.61 $\pm$ 3.47
Distance 15–20 km/h (km) — accumulated	14.58 $\pm$ 1.66	14.29 $\pm$ 1.61	17.21 $\pm$ 2.02	14.75 $\pm$ 1.84
Distance 15–20 km/h (km) — per 90 min	14.58 $\pm$ 1.66	14.29 $\pm$ 1.61	12.91 $\pm$ 1.52	14.37 $\pm$ 1.70
Distance >20 km/h (km) — accumulated	7.78 $\pm$ 1.13	7.75 $\pm$ 0.99	8.55 $\pm$ 1.01	7.84 $\pm$ 1.11
Distance >20 km/h (km) — per 90 min	7.78 $\pm$ 1.13	7.75 $\pm$ 0.99	6.41 $\pm$ 0.76	7.65 $\pm$ 1.13
Distance >25 km/h (km) — accumulated	2.10 $\pm$ 0.43	2.12 $\pm$ 0.38	2.27 $\pm$ 0.37	2.12 $\pm$ 0.42
Distance >25 km/h (km) — per 90 min	2.10 $\pm$ 0.43	2.12 $\pm$ 0.38	1.70 $\pm$ 0.27	2.07 $\pm$ 0.43
High-speed runs, 15–20 km/h (team total, n) — accumulated	1255 $\pm$ 136	1213 $\pm$ 134	1481 $\pm$ 166	1265 $\pm$ 154
High-speed runs, 15–20 km/h (team total, n) — per 90 min	1255 $\pm$ 136	1213 $\pm$ 134	1111 $\pm$ 125	1233 $\pm$ 140
Sprints, >20 km/h (team total, n) — accumulated	443 $\pm$ 55	435 $\pm$ 57	497 $\pm$ 59	446 $\pm$ 58
Sprints, >20 km/h (team total, n) — per 90 min	443 $\pm$ 55	435 $\pm$ 57	373 $\pm$ 44	435 $\pm$ 58
Peak top speed (km/h)	34.11 $\pm$ 0.98	34.41 $\pm$ 1.13	34.33 $\pm$ 0.98	34.19 $\pm$ 1.02
Mean player top speed (km/h)	30.04 $\pm$ 0.67	30.33 $\pm$ 0.55	30.30 $\pm$ 0.48	30.13 $\pm$ 0.64

Note. Team-match observations; each value is the sum over all players of one team in one match (goalkeepers included; 13–17 players, $M = 15.8$). Event counts are team totals, not per-player values: the corresponding per-player means are 80.1 high-speed runs and 28.3 sprints per match (Table 1). Per-90 values = accumulated value $\times$ 90 / nominal duration (90 or 120 min). Top-speed variables are not duration-dependent and are not normalised.

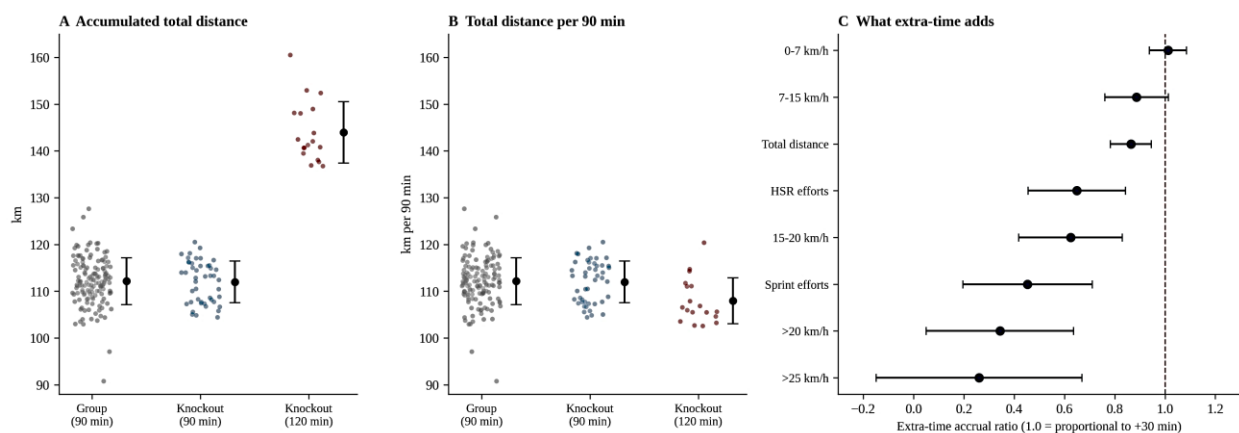


Figure 2. Team-match running output by match category. (A) Accumulated total distance. (B) Total distance per 90 min (nominal duration). Points are individual team-match observations; black markers show mean $\pm$ SD. (C) Extra-time accrual ratios with approximate 95% CI; the dashed line (1.0) indicates accrual at the regulation rate.

Primary analysis: accumulated total distance

In Model 1, knockout status was associated with 8.52 km more total distance (95% CI 4.73 to 12.30; $p < .001$; $\beta = 0.38$; marginal $R^2 = .145$; Table 3). Adding the extra-time indicator in Model 2 reduced the knockout coefficient to -0.52 km (-2.38 to 1.34 ; $p = .584$; $\beta = -0.02$), whereas extra-time was associated with 32.31 km (29.26 to 35.35 ; $p < .001$; $\beta = 0.89$). Model 2 fitted substantially better (likelihood-ratio $\chi^2(1) = 167.42$, $p < .001$), marginal R^2 increased to .764 ($\Delta R^2_m = .618$, 95% CI .549 to .683), and match-level variance fell from 79.56 to 12.82 km². The cluster-robust OLS estimates led to the same conclusion (Model 1 knockout $B = 8.84$ km, $p = .001$; Model 2 knockout $B = -0.16$ km, 95% CI -2.15 to 1.83 , $p = .876$).

Table 3. Crossed random-effects linear mixed models of accumulated total distance (km).

Term	B (km)	95% CI	p	β (standardised)	Nested comparison
Model 1: knockout status only					
Intercept (group phase)	112.13	109.91, 114.36	< .001	—	
Knockout	8.52	4.73, 12.30	< .001	0.38	
Variance: match / team / residual	79.56 / 7.44 / 4.33				
Marginal R^2 / conditional R^2	.145 / .959				
Model 2: knockout status + extra-time					
Intercept (group phase)	112.13	110.94, 113.33	< .001	—	
Knockout	-0.52	-2.38, 1.34	.584	-0.02	
Extra-time	32.31	29.26, 35.35	< .001	0.89	
Variance: match / team / residual	12.82 / 7.86 / 4.37				
Marginal R^2 / conditional R^2	.764 / .959				
Model comparison (Model 2 vs Model 1)	LRT $\chi^2(1) = 167.42$		< .001		$\Delta R^2_m = .618$ [.549, .683]

Note. $N = 208$ team-match observations nested in 104 matches and crossed with 48 teams; random intercepts for match and team; maximum likelihood. Null-model ICC: match = .890, team = .070. R^2 after Nakagawa and Schielzeth (2013); 95% CI for ΔR^2_m from 1,000 parametric bootstrap replicates. Sensitivity (OLS with two-way cluster-robust SEs by match and team): Model 1 knockout $B = 8.84$ km [3.61, 14.06], $p = .001$; Model 2 knockout $B = -0.16$ km [-2.15, 1.83], $p = .876$; extra-time $B = 31.98$ km [28.05, 35.92], $p < .001$.

Table 4. Duration-matched comparison: group-phase versus knockout matches completed in 90 minutes, unadjusted and adjusted for contextual covariates.

Variable	Group 90 min (n = 144)	Knockout 90 min (n = 46)	Cohen's d	B unadjusted [95% CI]	p	P (Holm)	B adjusted	p	p (Holm)
Total distance (km)	112.13 $\pm$ 5.00	111.98 $\pm$ 4.47	-0.03	-0.52 [-2.36, 1.33]	.584	1.000	1.10	.480	1.000
Distance 0–7 km/h (km)	43.63 $\pm$ 1.79	45.25 $\pm$ 2.23	0.85	1.11 [0.46, 1.75]	< .001	.008	1.11	.036	.322
Distance 7–15 km/h (km)	46.14 $\pm$ 3.26	44.69 $\pm$ 3.58	-0.44	-1.13 [-2.30, 0.05]	.060	.480	-0.17	.862	1.000
Distance 15–20 km/h (km)	14.58 $\pm$ 1.66	14.29 $\pm$ 1.61	-0.18	-0.34 [-0.94, 0.27]	.278	1.000	0.12	.819	1.000
Distance >20 km/h (km)	7.78 $\pm$ 1.13	7.75 $\pm$ 0.99	-0.03	-0.13 [-0.60, 0.34]	.593	1.000	0.05	.908	1.000
Distance >25 km/h (km)	2.10 $\pm$ 0.43	2.12 $\pm$ 0.38	0.04	-0.02 [-0.20, 0.16]	.813	1.000	0.01	.938	1.000
High-speed runs, 15–20 km/h (team total, n)	1255 $\pm$ 136	1213 $\pm$ 134	-0.31	-40.50 [-89.33, 8.34]	.104	.729	-9.31	.825	1.000
Sprints, >20 km/h (team total, n)	443 $\pm$ 55	435 $\pm$ 57	-0.15	-11.68 [-34.95, 11.59]	.325	1.000	-1.03	.959	1.000
Peak top speed (km/h)	34.11 $\pm$ 0.98	34.41 $\pm$ 1.13	0.29	0.19 [-0.15, 0.53]	.264	1.000	0.23	.417	1.000
Mean player top speed (km/h)	30.04 $\pm$ 0.67	30.33 $\pm$ 0.55	0.45	0.23 [0.00, 0.46]	.049	.440	0.46	.015	.152

Note. Values are mean $\pm$ SD. B from crossed random-effects LMMs (match, team), $n = 190$. Adjusted models include absolute final goal margin, total goals in the match, the team's ordinal match number in the tournament, and the opponent's final tournament stage (quality proxy). Variance inflation factors ≤ 3.11 . Environmental conditions, kick-off time and in-match score-line evolution were not available.

Convergent analyses of time-adjusted output

Per-90 total distance was 110.85 ± 4.91 km in the knockout phase and 112.13 ± 5.00 km in the group phase; the knockout coefficient was -1.57 km (-3.23 to 0.09 ; $p = .064$; $\beta = -0.15$; Figure 2B). In the duration-matched sample, group-phase matches (112.13 ± 5.00 km) and knockout matches completed in 90 minutes (111.98 ± 4.47 km) did not differ ($B = -0.52$ km, -2.36 to 1.33 , $p = .584$; $d = -0.03$). Adjustment for goal margin, total goals, ordinal match number and opponent stage did not change this result ($B = 1.10$ km, -1.95 to 4.15 , $p = .480$; all variance inflation factors ≤ 3.11), and none of the covariates was significantly associated with total distance (Table 4).

Table 5. Knockout effects across ten locomotor variables: accumulated (unadjusted and extra-time-adjusted), per-90, and extra-time accrual ratio.

Variable	Knockout B, unadjusted (p)	Knockout B adjusted for extra-time [95% CI]	p	P (Holm)	Knockout B per 90 min [95% CI]	p	p (Holm)	Extra-time accrual ratio [95% CI]
Total distance (km)	8.52 (< .001)	-0.52 [-2.38, 1.34]	.584	1.000	-1.57 [-3.23, 0.09]	.064	.127	0.86 [0.78, 0.95]
Distance 0–7 km/h (km)	5.18 (< .001)	1.04 [0.38, 1.70]	.002	.021	0.98 [0.42, 1.55]	< .001	.005	1.01 [0.94, 1.09]
Distance 7–15 km/h (km)	2.76 (.003)	-1.05 [-2.24, 0.14]	.083	.664	-1.35 [-2.37, -0.32]	.010	.051	0.89 [0.76, 1.01]
Distance 15–20 km/h (km)	0.52 (.108)	-0.33 [-0.94, 0.28]	.291	1.000	-0.69 [-1.24, -0.14]	.013	.053	0.62 [0.42, 0.83]
Distance >20 km/h (km)	0.11 (.599)	-0.14 [-0.60, 0.33]	.565	1.000	-0.49 [-0.92, -0.06]	.026	.077	0.34 [0.05, 0.64]
Distance >25 km/h (km)	0.03 (.694)	-0.02 [-0.20, 0.16]	.823	1.000	-0.13 [-0.29, 0.03]	.109	.127	0.26 [-0.15, 0.67]
High-speed runs, 15–20 km/h (team total, n)	36.6 (.174)	-39.4 [-89.0, 10.2]	.120	.838	-67.8 [-112.0, -23.5]	.003	.019	0.65 [0.45, 0.84]
Sprints, >20 km/h (team total, n)	6.5 (.557)	-12.3 [-35.5, 11.0]	.301	1.000	-28.4 [-49.5, -7.3]	.008	.051	0.45 [0.20, 0.71]
Peak top speed (km/h)	0.19 (.205)	0.20 [-0.14, 0.53]	.247	1.000	—	—	—	—
Mean player top speed (km/h)	0.25 (.011)	0.23 [0.02, 0.45]	.036	.320	—	—	—	—

Note. All models are crossed random-effects LMMs (match, team), $N = 208$. Holm adjustment within column family (10 variables for accumulated models; 8 volume variables for per-90 models). Accrual ratio = extra-time coefficient / (one third of the regulation group-phase mean); 1.0 indicates that the additional 30 min accrued the variable at the regulation rate. CI for the ratio treats the denominator as fixed and is therefore approximate. The accrual ratio refers to whole 120-min matches and cannot separate the extra period from pacing within the first 90 min.

Other locomotor variables

Before adjustment, knockout matches showed more accumulated distance at 0–7 km/h (5.18 km, $p < .001$) and 7–15 km/h (2.76 km, $p = .003$), but not in any zone above 15 km/h, in high-speed runs or sprints, or in peak top speed (Table 5). After adjustment for extra-time, only distance at 0–7 km/h remained higher in knockout matches (1.04 km, 0.38 to 1.70; Holm $p = .021$). In per-90 terms, knockout observations showed fewer high-speed runs (-67.8 per 90 min; Holm $p = .019$), more distance at 0–7 km/h (0.98 km; Holm $p = .005$) and non-significant tendencies towards lower distance in the 7–15, 15–20 and >20 km/h zones and fewer sprints (Holm $p = .051$ to $.077$).

The duration-matched comparison clarified the source of these per-90 differences (Table 4). Knockout matches completed in 90 minutes did not differ from group matches in distance at 15–20 km/h ($d = -0.18$), above 20 km/h ($d = -0.03$) or above 25 km/h ($d = 0.04$), or in high-speed runs or sprints (all Holm $p \geq .729$). They showed more distance at 0–7 km/h ($d = 0.85$; $B = 1.11$ km, 0.46 to 1.75; Holm $p = .008$), a difference that was attenuated after contextual adjustment (Holm $p = .322$), and a small, non-significant difference in mean player top speed ($d = 0.45$; Holm $p = .440$). The lower per-90 high-intensity output of the knockout

phase was therefore attributable to the extended matches rather than to knockout matches of regulation length.

Extra-time did not accrue output proportionally to its duration (Table 5; Figure 2C). Relative to the regulation rate, the additional 30 minutes accrued 101% of the expected distance at 0–7 km/h (95% CI 94 to 109%) and 86% of total distance (78 to 95%), but only 62% of distance at 15–20 km/h, 65% of high-speed runs, 45% of sprints, 34% of distance above 20 km/h (5 to 64%) and 26% of distance above 25 km/h (–15 to 67%).

Table 6. Sensitivity of the per-90 knockout effect on total distance to misspecification of match exposure time.

Scenario	Knockout B km per 90 min [95% CI or 2.5–97.5th percentile]	p / share significant	Interpretation
A. Deterministic tipping point (added-time differential applied to all knockout matches)			
Nominal durations (90 / 120 min), primary per-90 model	–1.57 [–3.23, 0.09]	.064	—
Point estimate crosses zero	0.00	—	Knockout matches ≈1.35 min shorter than assumed
Knockout per-90 distance significantly higher ($p < .05$)	≥ 1.73	$\leq .046$	Knockout matches ≥ 2.80 min shorter than assumed
Knockout per-90 distance significantly lower ($p < .05$)	≤ -1.69	$\leq .046$	Knockout matches ≥ 0.10 min longer than assumed
B. Monte Carlo, non-differential added time (1,000 replicates)			
Regulation U(4, 12) min; extra-time U(1, 4) min, drawn per match	–1.43 [–2.36, –0.44]	21.4% of replicates $p < .05$	0.2% of replicates $B > 0$
C. Monte Carlo, differential added time (1,000 replicates each)			
Knockout matches +3 min relative to group	–4.26 [–5.26, –3.30]	100.0% $p < .05$	all estimates negative
Knockout matches –3 min relative to group	1.56 [0.58, 2.52]	28.0% $p < .05$	100.0% of replicates $B > 0$
D. Invariant to duration assumptions			
Knockout B adjusted for extra-time indicator (Table 3, Model 2)	–0.52 [–2.38, 1.34]	.584	Uses no minute denominator

Note. Exposure-time data (actual added time) were not available in the tracking release. The added-time distributions in B–C are assumptions chosen to bracket plausible values, not observed data. All models are crossed random-effects LMMs, $N = 208$.

Sensitivity to exposure time

The per-90 knockout coefficient depended strongly on the assumed exposure (Table 6). The point estimate reached zero if knockout matches had, on average, 1.35 minutes less effective time than assumed relative to group matches; knockout per-90 distance became significantly higher only if knockout matches were at least 2.80 minutes shorter than assumed, and significantly lower if they were at least 0.10 minutes longer. Under non-differential random added time, the median knockout coefficient was –1.43 km per 90 min (2.5th–97.5th percentile –2.36 to –0.44); 21.4% of replicates reached $p < .05$ and 0.2% produced a positive estimate. With a three-minute differential, all replicates were significantly negative when knockout matches were longer, and 28.0% were significantly positive when they were shorter. By contrast, the extra-time-adjusted knockout coefficient in Model 2 does not depend on a minute denominator.

Running output and match outcome

In the 80 decided matches, winners covered 0.99 km more total distance per 90 min than losers, a difference that was not significant (–0.14 to 2.13; $p = .086$; Holm $p = .686$; $d_z = 0.19$; Table 7). The only difference that survived correction was distance at 0–7 km/h, which was higher in winners (1.43 km per 90 min, 1.03 to 1.83; Holm $p < .001$; $d_z = 0.80$) in 82% of matches, with similar effects in the group phase ($d_z = 0.78$) and the knockout phase ($d_z = 0.81$). Distance above 25 km/h was slightly higher in winners (0.09 km per 90 min; $p = .012$; Holm $p = .104$; $d_z = 0.29$). Running above 7 km/h did not differ between winners and losers (–0.43 km per 90 min; $p = .476$; $d_z = -0.08$), nor did distance at 15–20 or above 20 km/h, high-speed runs, sprints or top speed (all Holm $p \geq .812$).

Across all 104 matches, the within-match difference in per-90 total distance was positively correlated with the within-match goal difference ($r = .32$, 95% CI .13 to .48; Holm $p = .010$). This association was carried by distance at 0–7 km/h ($r = .55$, .40 to .67; Holm $p < .001$) and, to a lesser extent, distance above 25 km/h ($r = .31$, .13 to .47; Holm $p = .011$); running above 7 km/h was not associated with goal difference ($r = .06$, $p = .535$).

Table 7. Within-match paired comparison of duration-normalised running output between winning and losing teams, and association with goal difference.

Variable	Winners (n = 80)	Losers (n = 80)	M difference W – L [95% CI]	<i>p</i>	<i>P</i> (Holm)	<i>dz</i>	<i>dz</i> group (n = 52) / Knockout (n = 28)	Matches in which winner was higher (%)	<i>r</i> with goal difference, 104 matches (Holm <i>p</i>)
Total distance per 90 min (km)	112.64 ± 4.82	111.64 ± 5.40	0.99 [−0.14, 2.13]	.086	.686	0.19	0.21 / 0.16	57	.32 (.010)
Distance 0–7 km/h per 90 min (km)	44.90 ± 1.87	43.47 ± 2.19	1.43 [1.03, 1.83]	< .001	< .001	0.80	0.78 / 0.81	82	.55 ($< .001$)
Distance 7–15 km/h per 90 min (km)	45.43 ± 3.35	45.99 ± 3.59	−0.55 [−1.33, 0.22]	.160	.958	−0.16	−0.11 / −0.27	42	.02 (1.000)
Distance 15–20 km/h per 90 min (km)	14.47 ± 1.64	14.51 ± 1.75	−0.04 [−0.42, 0.34]	.822	1.000	−0.03	−0.04 / 0.00	46	.05 (1.000)
Distance >20 km/h per 90 min (km)	7.84 ± 1.20	7.68 ± 1.07	0.16 [−0.04, 0.36]	.116	.812	0.18	0.18 / 0.17	60	.20 (.303)
Distance >25 km/h per 90 min (km)	2.16 ± 0.44	2.07 ± 0.41	0.09 [0.02, 0.16]	.012	.104	0.29	0.34 / 0.19	62	.31 (.011)
High-speed runs, 15–20 km/h per 90 min (n)	1236 ± 135	1246 ± 147	−9.57 [−40.85, 21.72]	.544	1.000	−0.07	−0.11 / 0.03	44	.00 (1.000)
Sprints, >20 km/h per 90 min (n)	442 ± 61	437 ± 54	5.55 [−5.26, 16.37]	.310	1.000	0.11	0.14 / 0.06	57	.14 (.928)
Peak top speed (km/h)	34.28 ± 1.06	34.22 ± 0.95	0.06 [−0.21, 0.33]	.650	1.000	0.05	0.12 / −0.04	54	.07 (1.000)
Mean player top speed (km/h)	30.19 ± 0.56	30.18 ± 0.58	0.01 [−0.13, 0.16]	.854	1.000	0.02	0.09 / −0.11	49	.11 (1.000)

Note. Decided matches only (winner determined in regulation or extra-time; matches drawn in the group phase or settled by penalties excluded). *M* = Mean. Paired *t*-tests; *dz* = mean difference / SD of differences. Final column: Pearson correlation between within-match differences in the running variable and in goals across all 104 matches (orientation arbitrary but consistent for both variables). Running above 7 km/h per 90 min (sum of 7–15, 15–20 and >20 km/h): *W* – *L* = −0.43 km, $p = .476$, $dz = -0.08$; *r* with goal difference = .06, $p = .535$.

DISCUSSION

This study examined whether the higher accumulated running distance of the knockout phase at the 2026 World Cup reflected tournament phase or the unequal exposure created by extra-time. The unadjusted knockout excess of 8.52 km was large, yet it was eliminated once the extra-time indicator entered the model, with the adjusted coefficient close to zero and a confidence interval of about ± 2 km. Extra-time accounted for more than 32 km per team and for most of the explained variance. The hypothesis was supported, and the estimates are based on models that respect the cross-classified structure of the data.

The general lesson concerns the choice of denominator rather than extra-time as such. Accumulated distance answers a question about volume; it cannot answer a question about demand unless exposure is equal. At this tournament the phase comparison failed that condition because nine knockout matches lasted 120 minutes, and any analysis that compares raw totals across observations with different exposure will fail it in the same way. The term artefact is used here in this measurement sense: the knockout excess is produced by comparing quantities with unequal denominators. The data do not show that tournament phase has no effect on physical demand in a broader sense. Extra-time occurs only in the knockout phase, so the adjusted knockout coefficient is informed by knockout matches of regulation length, and the conclusion is

correspondingly specific: the difference in accumulated total distance between phases is eliminated once match extension is taken into account.

Three strategies pointed in the same direction, but they do not carry equal weight. The covariate-adjusted model and the duration-matched comparison both indicated no knockout effect on total distance, and the latter was unchanged by adjustment for goal margin, total goals, tournament progression and opponent stage. The per-90 comparison, in contrast, proved fragile: its direction depended on assumptions about added time of the order of one to three minutes, which is well within the variation seen between matches. The earlier impression that knockout matches were marginally less demanding per unit time is therefore not supported; the defensible statement is that no difference in total-distance work rate could be detected within the precision of the available exposure data. This fragility is itself an instance of the measurement principle. Per-90 values are only as accurate as the exposure denominator, and the primary result is robust precisely because it does not depend on one.

The multi-variable analysis shows what extra-time adds. The extra 30 minutes accrued low-speed distance at the regulation rate, total distance at 86% of that rate and distance above 20 km/h at about one third of it. This gradient is consistent with the reductions in relative and high-intensity output reported during extra-time (Field et al., 2022; Kubayi & Toriola, 2018; Lago-Peñas et al., 2015; Mohr et al., 2023) and explains why the per-90 high-intensity output of the knockout phase as a whole was lower: extended matches dilute intensity. Knockout matches of regulation length did not differ from group matches in high-speed running, high-intensity distance, sprint distance or sprint counts. Two caveats apply. The accrual ratios are based on whole 120-minute matches and cannot separate reduced output during extra-time from pacing earlier in those matches. In addition, the greater low-speed distance of knockout matches in regulation time may reflect longer stoppages, which would imply more effective exposure in those matches and would reinforce, rather than weaken, the absence of a higher knockout work rate.

The outcome analysis replaces the pooled points variable of the earlier version, which was not comparable across phases. The paired design gives a more nuanced picture than a simple absence of association. Winners and losers did not differ in running above 7 km/h, in any high-speed zone or in sprint counts, and total distance per 90 min did not differ significantly. The only robust difference was that winners covered more distance below 7 km/h, in both phases and in more than four of every five matches, and this low-speed component also carried the positive correlation between running and goal difference. The most plausible explanation is reverse direction through game state: teams that ahead tend to control tempo and circulate the ball, whereas trailing teams alter their running profile to recover the deficit (Bradley & Noakes, 2013; Paul et al., 2015). Minute-by-minute score-line data would be required to test this directly. The findings agree with the view that locomotor volume is a weak determinant of success (Andrzejewski et al., 2022; Aquino et al., 2021; Barthelemy et al., 2024; Carling, 2013; Chmura et al., 2022; Oliva-Lozano et al., 2023) and indicate that, where associations with outcome exist, the outcome may shape the running rather than the reverse. The small association of distance above 25 km/h with goal difference did not survive correction in the paired contrast and should be regarded as exploratory.

For practitioners the implication is a choice of metric matched to the question, summarised in Table 8 and Figure 1. Accumulated volume is appropriate when estimating recovery burden or cumulative tournament load; an extended match imposes more total work regardless of intensity, and recovery planning should reflect this. Relative work rate, preferably based on effective exposure time rather than nominal duration, is appropriate for comparing matches or phases of unequal length. Peak-intensity measures based on rolling windows or speed and acceleration thresholds are appropriate for training specificity and worst-case

preparation. Comparisons across tournament phases, and any comparison involving unequal minutes, should include an exposure term or be restricted to observations of equal duration, and should report which of the three constructs is being addressed.

Table 8. Metric-selection framework: matching the analytical question to the quantity and denominator.

Practical question	Construct	Denominator	Example metric	Typical application
How much locomotor work did the team or player accrue in this match or tournament?	Accumulated volume	None (raw total)	Total distance, total high-speed distance	Estimating recovery burden and cumulative tournament load; planning post-match recovery after extended matches
Did the team work harder per unit of time in match A than in match B?	Relative work rate	Exposure time (min), ideally effective time including added time	Distance per minute or per 90 min	Comparing matches or phases of unequal duration; comparing substitutes with starters
How intense were the most demanding periods?	Peak intensity	Fixed rolling window (e.g., 1–10 min) or speed/acceleration threshold	Peak distance per window, high-intensity distance, sprints, accelerations	Designing training drills; worst-case scenario preparation
Is a between-group difference in accumulated volume due to demand or to exposure?	Exposure-adjusted comparison	Duration covariate or duration-matched subset	Model with exposure indicator/offset; duration-matched comparison	Any comparison across tournament phases, competitions with extra-time, or unequal minutes played

Note. Adapted from the present findings; constructs correspond to Figure 1. Per-90 values are only as accurate as the exposure denominator (see Table 6).

Several limitations should be acknowledged. The data derive from a single men's tournament, and the prevalence of extra-time, tactical characteristics, environmental conditions and tracking procedures may differ elsewhere; replication is essential rather than optional. Analyses were conducted at team level; positional and individual responses were not examined. Exposure was approximated by nominal duration because effective playing time was not available, and the sensitivity analysis shows that per-90 inferences depend on this approximation. The locomotor variables were limited to distance, speed-zone and top-speed measures; accelerations, decelerations, metabolic power and peak rolling-window demands were not available, so the conclusions are restricted to the variables analysed and do not establish that knockout matches are equivalent in every dimension of physical demand. Contextual adjustment was limited to variables recoverable from the match record; environmental conditions, kick-off time and in-match score-line evolution could not be modelled. Finally, the observational design does not support causal claims beyond the arithmetic of accumulation.

Future work should adopt a preregistered, multi-tournament design that includes men's and women's competitions, models player-level clustering, uses effective exposure time, and extends the analysis to acceleration-based and peak-intensity measures. Such a design would establish whether the pattern described here generalises and would position exposure normalisation as a routine element of match-demand analysis.

CONCLUSIONS

The higher accumulated total distance observed in the knockout phase of the 2026 World Cup was eliminated once the additional exposure of extra-time was taken into account, and knockout matches of regulation length

did not differ from group matches in total, high-speed or sprint output. Extra-time added volume at markedly reduced intensity, particularly above 20 km/h. Per-90 phase comparisons were sensitive to small errors in exposure time, and duration-normalised running above 7 km/h did not distinguish winners from losers. Accumulated volume, relative work rate and peak intensity should be treated as distinct constructs, each with its own denominator, and comparisons of physical output across observations of unequal exposure should account for that exposure explicitly.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Contributions are specified according to the CRediT (Contributor Roles Taxonomy) as follows:

Conceptualisation: Danail Ivanov, Grigor Gutev. Methodology: Danail Ivanov, Grigor Gutev. Formal analysis: Danail Ivanov, Grigor Gutev. Investigation: Iva Dimova. Data curation: Iva Dimova. Writing – original draft: Danail Ivanov, Grigor Gutev. Writing – review & editing: Danail Ivanov, Grigor Gutev. Supervision: Iva Dimova.

All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

ETHICS AND LEGAL COMPLIANCE

This study analysed publicly released, aggregated team-level competition data; it involved no intervention on human participants and no identifiable personal information beyond publicly reported match statistics and therefore did not require ethics committee approval. The study complies with the current laws of the country in which it was performed.

DATA AVAILABILITY

The derived team-match dataset and all result tables are provided as a supplementary file.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, Generative artificial intelligence was used in preparing this revision: Claude (model Claude Opus 5; Anthropic, San Francisco, CA, USA), accessed through claude.ai in September 2026. The tool was used to write and execute the statistical analysis code (Python), to produce the tables and figures, to draft the revised manuscript text and

the response to reviewers, and to check reference metadata against PubMed. The research question, the data and the study design originate from the authors, and the methodological changes made in response to the reviewers were approved by the authors. The authors reviewed the analyses, the text and the references and take full responsibility for the content of the manuscript. The analysis scripts are available from the corresponding author on request. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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