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How much running is too much? Identifying high-risk running sessions in a 5200-person cohort study

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► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bjsports-2024-109380).

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Accepted 11 June 2025

ABSTRACT

Objectives We explored whether a spike in running distance during a single session or over 1 week, compared with the preceding period, was associated with increased risk of running-related overuse injury.

Methods Adult runners were recruited for an 18-month cohort study. Three training-related exposures were defined based on a relative change in running distance, using data collected via Garmin devices: (1) session-specific running distance relative to the longest distance run in the past 30 days; (2) 1-week period relative to the preceding 3 weeks using the acute:chronic workload ratio (ACWR); (3) 1-week period using a week-to-week ratio. Runners were categorised into one of four time-varying states: (1) regression, or up to 10% increase (reference); (2) 'small spike' between >10% and 30% increase; (3) 'moderate spike' between >30% and 100% increase; and (4) 'large spike' >100% increase. Outcome was self-reported overuse running-related injury. A multistate Cox regression model was used to estimate adjusted hazard rate ratios (HRR).

Results Among 5205 runners (mean age 45.8 years, SD=10.4; 22% female), a total of 1820 (35%) sustained a running-related injury during 588 071 sessions. Significantly increased rates were identified for small spikes (HRR=1.64 (95% CI: 1.31 to 2.05, p=0.01)), moderate spikes (HRR=1.52 (95% CI: 1.16 to 2.00, p<0.01)) and large spikes (HRR=2.28 (95% CI: 1.50 to 3.48, p<0.01)) in single-session running distance. A negative dose-response relationship was observed for the ACWR. No relationship was identified for the week-to-week ratio.

Conclusion A significant increase in the rate of running-related overuse injury was found when the distance of a single running session exceeded 10% of the longest run undertaken in the last 30 days.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Distance running has grown in popularity and is practiced by millions of individuals globally for a variety of recreational and competitive purposes.

⇒ Running 'too much' before musculoskeletal structures achieve adequate tolerance to withstand the external applied load is recognised as a major contributor to injury occurrence.

⇒ Acute:chronic workload ratio and week-to-week ratio are commonly used in scientific studies and implemented in practice (eg, in wearable devices) to guide runners towards a safe increase in running distance.

WHAT THIS STUDY ADDS

⇒ Session-specific running distances that are ≥10% of the longest run undertaken in the prior 30 days significantly increase the risk of lower extremity injury.

⇒ Caution is advised when relying on recommended training load calculations such as the acute:chronic workload ratio and weekly-gradual changes, as no association, or even inverse associations, between these approaches and injury risk was found.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Based on our novel findings and the largest study conducted to date on this topic, healthcare professionals, coaches and athletes are encouraged to adopt this new single-session paradigm and promote a safer approach to maximal progression in running distance.

Check for updates

To cite: Schuster Brandt Frandsen J, Hulme A, Parner ET, *et al*. *Br J Sports Med* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/bjsports-2024-109380

INTRODUCTION

Running is a popular form of exercise, embraced for a variety of reasons including competition, recreation, social engagement and health improvement.[1 2] Globally, millions run due to its affordability and accessibility.[3] Over 90% of regular runners use Global Positioning System (GPS) wearables to monitor training loads, with the aim of enhancing performance and managing the risk of running-related injury.[4] Despite this, the rate of running-related injury has remained high.[5 6] Today, injury is the main reason for discontinuing a running programme.[7–9] Therefore, understanding the causes of injury is crucial to offer evidence-based advice, treatment and support for safe exercise habits.

Excessive training and overlooking physical limitations are key factors in the development of running-related injury, as highlighted in a few qualitative studies.[10–12] This aligns with causal sports injury frameworks developed over the past 15 years, emphasising the 'too much, too soon' theory, which suggests that injury occurs when runners increase distance too rapidly.[13 14] While widely accepted among clinicians, researchers, coaches and athletes,[10 15] defining 'too much' remains debated. Traditional sports injury epidemiological studies[16] use the acute:chronic workload ratio (ACWR) and the week-to-week ratio to quantify change in load over time.[17–19] These methods, adopted by industry and used by runners globally, equate the 'too much' period to 1 week.[20] Load progression or regression is calculated by dividing the 1-week load by the applied loads from the previous one to 4 weeks, reflecting the gradual development of overuse injuries across multiple running sessions.[15 21]

Although weekly training load metrics like the ACWR are widely used, new paradigms in sports injury aetiology should be explored. The unique physical demands of each sport give rise to distinct injury mechanisms. In running, emerging evidence from our research shows that few runners report symptoms before an injury occurs.[22] This suggests that runners may be more vulnerable when increasing distance too rapidly within a single session, indicating that the 'too much' period for running injuries may be shorter than the 1-week window commonly used in research and wearable devices. If validated, this 'single-session paradigm' could provide new insights into the development of overuse injuries, offering healthcare professionals more precise guidance for injury prevention and patient well-being.

This study aimed to explore whether a spike in kilometres run, either in a single session or over a 1-week period compared with the preceding period, was associated with an increased rate of overuse running-related injury.

METHODS

Study design

This explorative study uses longitudinal data from the Garmin-RUNSAFE Running Health study with an 18-month follow-up.[23] Runners signed an online informed consent form prior to inclusion and could withdraw at any time during the study period. Enrolment occurred between 4 July 2019 and 1 December 2019, and the study followed up until January 2021. Reporting followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guideline and statistics, interpretation and reporting was checked for consistency using the CHAMP (CHecklist for statistical Assessment of Medical Papers) checklist.[24]

Participants

Garmin (Olathe, Texas, USA) was responsible for recruiting English-speaking runners who had accepted receiving Garmin-related newsletters by email. In addition, the RUNSAFE research group recruited through European-based running clubs and magazines. Confirmation emails for enrolment were sent to runners if they agreed to participate, and those who answered enrolment questionnaires were considered for inclusion. Eligible participants were expected to: (1) wear a Garmin GPS device and upload running data via the 'Garmin Connect' app; and (2) be willing to respond to weekly questionnaires covering injury/problem status and anatomical location. Participants were excluded if they met any of the following criteria: (1) had an existing musculoskeletal problem at baseline; (2) failed to respond to the baseline questionnaire and/or failed to answer any of the weekly questionnaire; (3) did not record any running activity; (4) had a running-related injury during follow-up yet failed to report the origin as being based on a traumatic or non-traumatic (ie, repetitive mechanism) onset; (5) had more than 10 days between a self-reported injury during follow-up and their last running session; and (6) only ran sessions below the distance of 500 m or above the distance of 100 km due to the risk of data error.

Procedures

Self-reported data, including age, height and weight, were collected via an enrolment questionnaire. Sex, running experience and previous injuries were reported at baseline, whereas injury/problem status and anatomical location were obtained from the weekly questionnaires. Data on running activity, including kilometres covered in each running session, was collected via wearable Garmin devices. All runners wore Garmin devices capable of transferring data from each running session, assessed in a valid manner by GPS and/or accelerometry, to the runner's smartphones.[25 26] Data were sent from the Garmin Connect application to Aarhus University servers and the RUNSAFE group via an application programming interface solution (Health API).

Exposure

The primary exposure was the ratio of the distance covered in a single running session relative to the longest session undertaken in the preceding 30 days. The exposure was time-varying; hence runners could change their exposure status each time they completed a running session. The relative change (in per cent) in single-session running distance was calculated using data from the activity records related to running. Data were collapsed such that running sessions with less than 15 min of pause between them were counted as a single session rather than multiple running sessions. This aggregation included data from interval training and other high-intensity sessions. The distance covered in a single running session, for example, 12 000 m, was divided by the longest distance covered in each session undertaken in the 30-day period (eg, 8000 m) preceding the current running day. In the above example, the calculation 12 000 m/8000 m resulted in a ratio of 1.5, signifying a 50% increase in running distance. A relative change of >1 indicated progression (increase), while a change of <1 indicated regression (decrease).

As the injury rate as a function of relative change in running distance deviated from a linear relationship, relative changes were categorised into one of the following five transition states: (1) regression (running less than the longest run), or up to 10% progression (reference); (2) small spike corresponding to a progression between >10% and 30%; (3) moderate spike corresponding to a progression between >30% and 100%; (4) large spike corresponding to a progression above 100%; and (5) not possible (NP) to calculate a relative change since the denominator was zero (NP-state). A 10% cut-off was used given the significance of the '10% rule' in running communities,[20] whereas a 30% increase was selected since progression in weekly averaged running distance exceeding this amount has been associated with increased risk of injury.[17 18 27] A 100% cut-off was chosen as it represents doubling in running distance. As cut-off values can be discussed, the relative injury hazard as a function of change in running distance as a continuous variable will be visualised in the results section.

In addition to the calculation of single-session changes, the uncoupled ACWR was calculated using the most recent 1-week acute workload (sum of distance in all running sessions) and the prior 3-week chronic workload as described by Gabbett *et al*.[28] Finally, the week-to-week ratio was calculated using the same 1-week acute workload as used in the ACWR divided by the sum of distance in all running sessions in the week prior to this as described by Nielsen *et al*.[18] For ACWR and week-to-week ratios, the same cut-offs as described above for calculation of change in single-session running distance were used when categorising runners into a transition state after each running session.

Outcome

The main outcome was the first-occurring self-reported overuse running-related injury, while injuries based on a traumatic onset were considered as competing risks. Information about injury status was assessed through an automated weekly questionnaire. Runners classified themselves into one of three categories based on the following question: 'In the past week, have you had a musculoskeletal injury, or have you experienced a problem to muscles, tendons or bones that is fully or partly caused by running'? The categories were: (1) injury-free; (2) uninjured yet with problems; or (3) injured. Of these, the categories injury-free and uninjured were merged in the sense that only those reporting an injury (number 3) had an outcome. Runners were informed that a problem was less severe than an injury, defined as being painful and irritating; however, running activities continued unabated in terms of volume, intensity and frequency. Injuries were painful and irritating, leading to a reduction in running activity (ie, volume, intensity, frequency). The injured runner was required to specify the mechanism of injury, categorised as either overuse (non-traumatic) or traumatic (such as torsion, a fall or blow). The definition of a running-related problem and injury was informed by the running injury consensus definition by Yamato *et al* as well as the Oslo Trauma Research Center questionnaire.[29 30] When an injury was not reported on the day of the running session, it was linked to the last recorded running session up to 10 days before the injury. If an injury was reported more than 10 days after the completion of a running session, the runner was excluded.

Confounding

Visualising the causal assumptions in a directed acyclic graph (DAG) has been recommended within the causal inference domain of medicine.[24] In the present study, the confounders included in the DAG were: previous problems, body mass index (BMI), sex, age and years of running experience (online supplemental S1). Previous running-related problems prior to baseline were included as a confounder given that this is a well-known risk factor for running-related injury and may be associated with running distance.[31] Likewise, there may be differences in injury risk between the sexes, including the intensity and duration of longer runs.[32 33] A higher BMI places greater stress on musculoskeletal structures compared with a lower BMI which, all else equal, has been consistently associated with an elevated risk of injury.[31 32] Finally, age and running experience were included as confounders, as these factors have been associated with injury development.[32 33] The requirements regarding events per variable were fulfilled owing to a considerable number of injuries in the present dataset.[34]

Statistical analysis

As the present study was exploratory, no sample size or power calculation was made a priori. While change in running distance was calculated as a ratio based on kilometres run, data were analysed using running sessions as the time scale. A multistate Cox regression model was applied using time to first injury consisting of two absorbing states (main injury and competing risk injury) and the five transient states earlier outlined under 'Exposure'.[35–37] The assumption of proportional rates was assessed using log-log plots of the Grambsch and Therneau test based on Schoenfeld residuals. While producing the figures, sessions with NP-state increases or increases of more than 900% were excluded to enable a stable Cox model. Data management and analysis were made in R V.4.3.3 (Austria, Vienna). R-code can be found in online supplemental S2, while results from various sensitivity analyses can be found in online supplemental S4–S8.

Equity, diversity and inclusion statement

The author team comprises individuals of different genders (five women and eight men) and nationalities (Denmark,

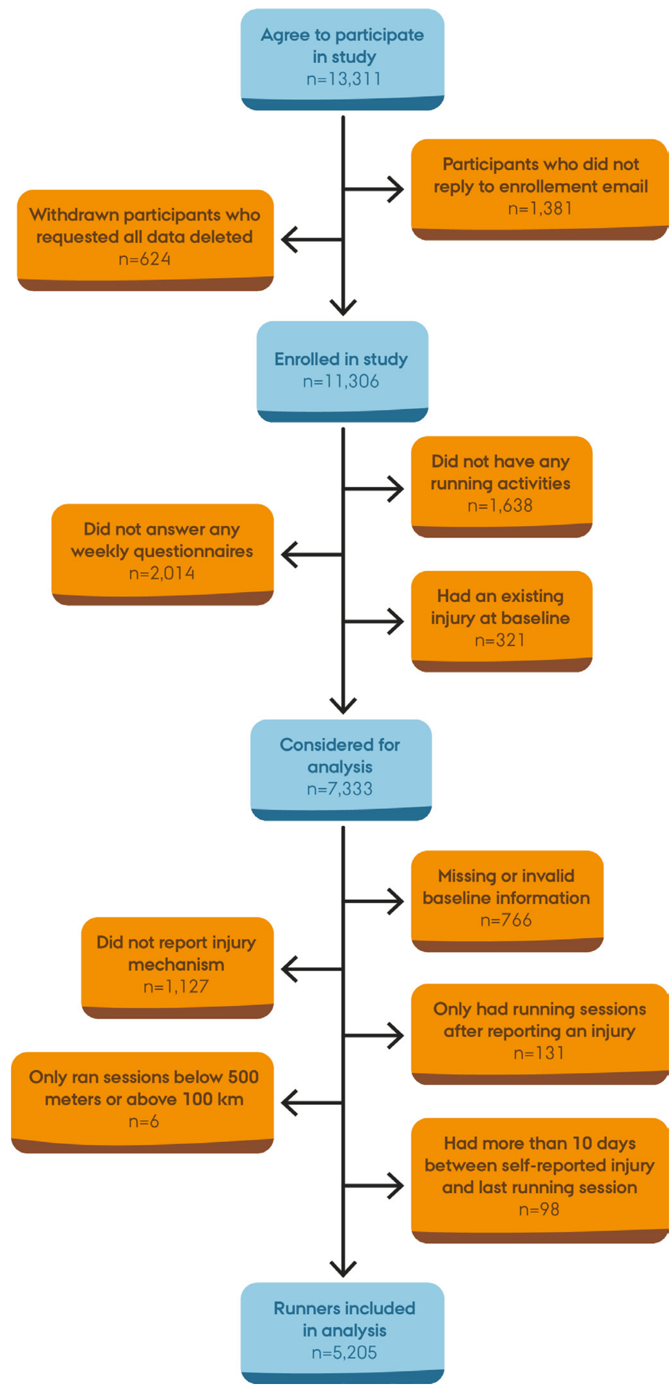

Figure 1 Flowchart visualising the inclusion of runners into the present study.

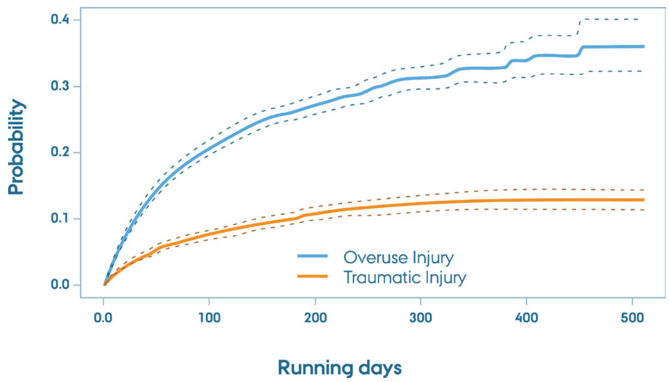

Figure 2 Aalen-Johansen plot visualising the probability of sustaining overuse and traumatic running-related injuries (y-axis) as a function of running sessions (x-axis). At 200 km, 30.5% (95% CI: 29.0% to 32.0%) reported an overuse injury and 12.0% (95% CI: 11.0% to 13.1%) had reported a traumatic injury.

Sweden, Australia, Luxembourg), bringing multiple perspectives to the research. The study aimed to recruit a diverse participant population from 87 countries, ensuring representation across sex, ages and BMI. Efforts were made to include all types of runners, including those with comorbidities, to enhance the diversity of the study sample. We acknowledge that while running is a relatively affordable sport allowing everybody to participate, the requirement for participants to use a Garmin watch may limit inclusivity for some socioeconomic groups.

RESULTS

A total of 5205 runners, predominantly from Europe and North America, were included in the analysis. Of these, 4053 (77.9%) were male and 1152 (22.1%) were female. The mean age of the participants was 45.8 years (SD=10.4), with a BMI of 24.2 kg/m^2 (SD=3.6). The median running experience was 9.5 years (IQR: 4–20 years). The median time at risk was 80.0 (IQR: 31–161) running sessions with a total of 588 071 sessions. Figure 1 depicts a flow chart of runners at each stage from consideration until inclusion.

Of the 5205 runners, a total of 1820 (35.0%) reported a running-related injury, of which 1311 (72.0%) were classified as overuse injuries (main outcome), and 509 (28.0%) as traumatic injuries (competing risk). Most of these injuries were reported on the same day as the running session or the following 1–2 days after the running session (online supplemental S3). An Aalen-Johansen plot visualising the proportion of runners sustaining overuse and traumatic injuries as a function of running sessions is presented in figure 2. At 200 sessions, 30.5% (95% CI: 29.0% to 32.0%) had reported an overuse injury and 12.0% (95% CI: 11.0% to 13.1%) had reported a traumatic injury.

The main results are presented in table 1. Relative to running less than the longest run or a progression≤10% (the reference), significantly increased rates were identified for small spikes (hazard rate ratio (HRR)=1.64 (95% CI: 1.31 to 2.05, p=0.01)), moderate spikes (HRR=1.52 (95% CI: 1.16 to 2.00, p<0.01)) and large spikes (HRR=2.28 (95% CI: 1.50 to 3.48, p<0.01)) in kilometres in a single running session for the 1311 overuse running-related injuries. Conversely, the point estimates and CIs in table 2 revealed that small, moderate and large spikes in weekly running dose were associated with a significantly decreased rate of injury if the calculation of change in running distance was based on the ACWR. In contrast, no significant relationship was identified for the week-to-week ratio (table 3). Figure 3 visualises the development of the HRR for overuse injuries as a function of change in single-session running distance change, of change in the uncoupled ACWR, and for change in the week-to-week ratio, respectively. In online supplemental S4–S8, sensitivity analyses are presented using other outcome definitions and/or cut-offs. Collectively, these results revealed an increased rate for all running-related injuries and certain types of these injuries with an increase in single session running distance (online supplemental S4–S6 and S8). In addition, changing cut-offs from 10% to 1% revealed an increase in distance from 1% to 10% to be associated with an increased injury rate (online supplemental S7).

DISCUSSION

Training errors are considered the main contributor to overuse injury development in runners.[13] The present study identified a dose-response relationship between a spike in the number of kilometres run during a single running session and running injury development (table 1). Increased hazards of 64%, 52% and 128% for small (>10% to 30%), moderate (>30% to

Table 1 Changes in session-specific running distance and hazards of sustaining running-related injuries

Exposure groups	n	Label	HRR_{Crude}	95% CI	P value	$HRR_{Adjusted}$	95% CI	P value
Overuse injuries								
Change from 0 to 1.1	1117	Regression or progression to 10%	1 (ref)	(-)	–	**1 (ref)**	**(-)**	**–**
Change from>1.1 to 1.3	81	Minor spike from>10% to 30%	1.64	(1.31 to 2.06)	<0.01	**1.64**	**(1.31 to 2.05)**	**<0.01**
Change from>1.3 to 2.0	56	Medium spike from>30% to 100%	1.51	(1.15 to 1.99)	<0.01	**1.52**	**(1.16 to 2.00)**	**<0.01**
Change above 2.0	24	Large spike more than 100%	2.27	(1.49 to 3.46)	<0.01	**2.28**	**(1.50 to 3.48)**	**<0.01**
N/P	33	Not possible to calculate a change	0.80	(0.40 to 1.60)	0.52	**0.80**	**(0.40 to 1.61)**	**0.54**
Traumatic injuries								
Change from 0 to 1.1	430	Regression or progression to 10%	1 (ref)	(-)	–	1 (ref)	(-)	–
Change from>1.1 to 1.3	30	Minor spike from>10% to 30%	1.54	(1.06 to 2.24)	0.02	1.56	(1.07 to 2.26)	0.02
Change from>1.3 to 2.0	24	Medium spike from>30% to 100%	1.60	(1.05 to 2.45)	0.03	1.63	(1.06 to 2.49)	0.03
Change above 2.0	8	Large spike more than 100%	1.74	(0.82 to 3.70)	0.15	1.79	(0.84 to 3.80)	0.13
N/P	17	Not possible to calculate a change	1.27	(0.52 to 3.10)	0.59	1.36	(0.56 to 3.31)	0.50

Results are presented for overuse injuries (main result highlighted with bold) and traumatic injuries, respectively, among the 5205 runners included in the analyses.
The adjusted results were adjusted for age, BMI, sex, previous problems and running experience.
BMI, body mass index; HRR, hazard rate ratio; n, number of injuries in the corresponding state; N/P, not possible to calculate a change; ref, reference.

Table 2 Acute:chronic workload ratio running distance and hazards of sustaining running-related injuries

Exposure groups	n	Label	HRR_{Crude}	95% CI	P value	$HRR_{Adjusted}$	95% CI	P value
Overuse injuries								
Change from 0 to 1.1	432	Regression or progression to 10%	1 (ref)	(-)	–	**1 (ref)**	**(-)**	–
Change from>1.1 to 1.3	174	Minor spike from>10% to 30%	0.94	(0.79 to 1.12)	0.47	**0.94**	**(0.79 to 1.12)**	**0.47**
Change from>1.3 to 2.0	275	Medium spike from>30% to 100%	0.87	(0.75 to 1.02)	0.08	**0.87**	**(0.75 to 1.02)**	**0.08**
Change above 2.0	79	Large spike more than 100%	0.76	(0.60 to 0.96)	0.02	**0.75**	**(0.59 to 0.96)**	**0.02**
N/P	352	Not possible to calculate a change	0.59	(0.50 to 0.71)	<0.01	**0.59**	**(0.50 to 0.71)**	**<0.01**
Traumatic injuries								
Change from 0 to 1.1	157	Regression or progression to 10%	1 (ref)	(-)	–	1 (ref)	(-)	–
Change from>1.1 to 1.3	48	Minor spike from>10% to 30%	0.69	(0.50 to 0.95)	0.02	0.68	(0.49 to 0.95)	0.02
Change from>1.3 to 2.0	89	Medium spike from>30% to 100%	0.78	(0.60 to 1.01)	0.06	0.78	(0.60 to 1.01)	0.06
Change above 2.0	39	Large spike more than 100%	1.08	(0.76 to 1.53)	0.69	1.08	(0.76 to 1.54)	0.66
N/P	176	Not possible to calculate a change	0.88	(0.67 to 1.15)	0.34	0.9	(0.68 to 1.17)	0.42

Results are presented for overuse injuries (main result highlighted with bold) and traumatic injuries, respectively, among the 5205 runners included in the analyses.
The adjusted results were adjusted for age, BMI, sex, previous problems and running experience.
BMI, body mass index; HRR, hazard rate ratio; n, number of injuries in the corresponding state; N/P, not possible to calculate a change; ref, reference.

100%) and large spikes (>100%) were found, respectively. In contrast, significant decreases in injury rates were identified for spikes above 10% using the ACWR (table 2). Although the ACWR is widely used in research within a team-sport setting, there is a paucity of knowledge on the association between ACWR and running-related injury.[17 38] To the best of our knowledge, only one 435-runner cohort study has previously examined the link between ACWR and running-related injury.[39] That study reported findings that closely align with those of the present analysis, suggesting that a higher ACWR is associated with a lower risk of running-related injury.[39] No significant differences were present for week-to-week ratio (table 3 and figure 3). This finding also corroborates results in an 874-person cohort of novice runners and a study on 434 youth cross-country runners.[18 40] Collectively, these findings suggest a paradigm shift in understanding running-related injuries, indicating that most injuries occur due to an excessive training load in a single session, rather than gradual increases over time.

This study challenges the use of traditional load monitoring approaches, including the ACWR in the context of running-related injury occurrence. The single-session paradigm is therefore suggested as a novel approach to detecting deleterious spikes in running distance. Runners should avoid running a distance in their current session that exceeds 10% of the longest distance covered in the previous 30 days. However, progressions up to 10% are not necessarily safe either and carry a degree of risk. Although not statistically significant, a progression between 1% and 10% translated into an increased rate of 19% (95% CI: −10% to 57%, p=0.22) compared with regression or progression up to 1% (results not shown in table 1). This is confirmed in figure 3 where progressions up to 10% appear to slightly increase the risk of injury. The current findings apply to a single running session and do not account for continuous progression over multiple sessions. For example, if the longest distance covered by a runner in the past 30 days was 10 km, then running 11 km, 12.1 km and 13.3 km in subsequent sessions within the same week, despite each reflecting a 10% increase, may still be considered excessive due to insufficient recovery time. Therefore, determining a safe progression in kilometres involves considering various factors beyond only the longest distance covered in the past 30 days.

The strengths of the present study include its considerably large sample size of 5205 runners, or approximately five times larger than the largest sample reported in previous prospective cohort studies, which have typically ranged from 100 to 1000 participants.[18 39 41–44] Further strengths include the

Table 3 Week-to-week change in running distance and hazards of sustaining running-related injuries

Exposure groups	n	Label	HRR_{Crude}	95% CI	P value	$HRR_{Adjusted}$	95% CI	P value
Overuse injuries								
Change from 0 to 1.1	520	Regression or progression to 10%	1 (ref)	(-)	–	**1 (ref)**	**(-)**	–
Change from>1.1 to 1.3	158	Minor spike from>10% to 30%	0.97	(0.81 to 1.16)	0.75	**0.97**	**(0.81 to 1.16)**	**0.75**
Change from>1.3 to 2.0	262	Medium spike from>30% to 100%	0.88	(0.76 to 1.02)	0.11	**0.88**	**(0.76 to 1.02)**	**0.11**
Change above 2.0	217	Large spike more than 100%	0.91	(0.77 to 1.07)	0.29	**0.91**	**(0.78 to 1.07)**	**0.29**
N/P	155	Not possible to calculate a change	0.7	(0.56 to 0.88)	<0.01	**0.7**	**(0.56 to 0.88)**	**<0.01**
Traumatic injuries								
Change from 0 to 1.1	187	Regression or progression to 10%	1 (ref)	(-)	–	1 (ref)	(-)	–
Change from>1.1 to 1.3	51	Minor spike from>10% to 30%	0.86	(0.64 to 1.18)	0.33	0.86	(0.63 to 1.17)	0.33
Change from>1.3 to 2.0	112	Medium spike from>30% to 100%	1.05	(0.83 to 1.33)	0.71	1.05	(0.83 to 1.32)	0.72
Change above 2.0	88	Large spike more than 100%	1	(0.77 to 1.29)	0.99	1	(0.77 to 1.30)	0.99
N/P	71	Not possible to calculate a change	0.82	(0.56 to 1.19)	0.33	0.84	(0.57 to 1.22)	0.33

Results are presented for overuse (main result highlighted with bold) and traumatic injuries, respectively, amongst the 5205 runners included in the analyses.
The adjusted results were adjusted for age, BMI, sex, previous problems and running experience.
BMI, body mass index; HRR, HR ratio; n, number of injuries in the corresponding state; N/P, not possible to calculate a change; ref, reference.

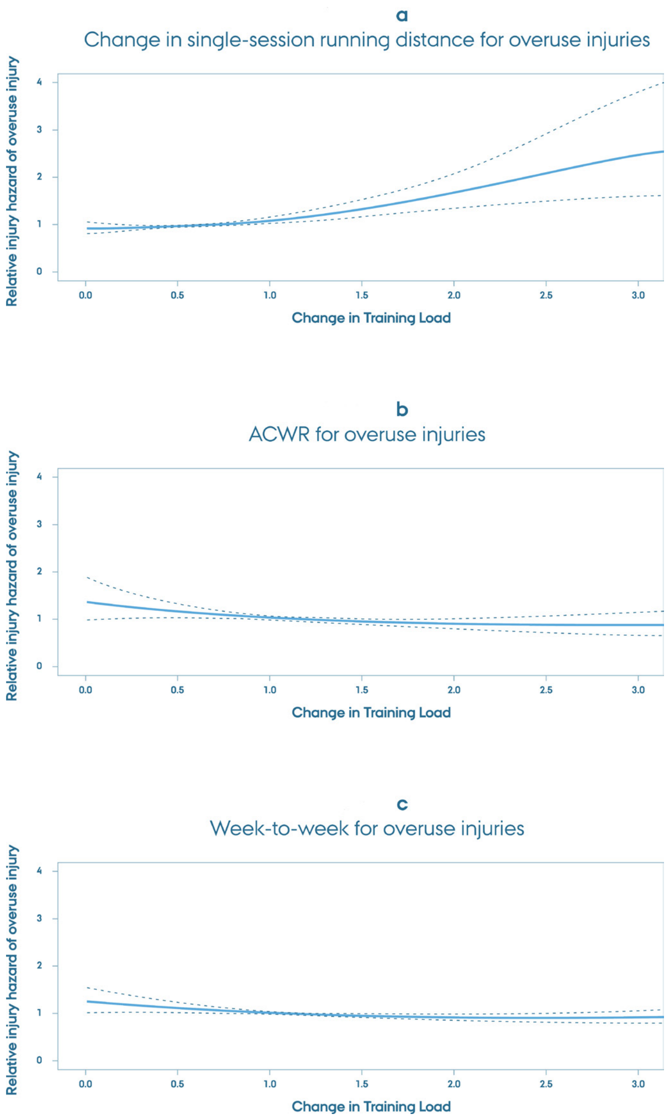

Figure 3 Plot of overuse injury HRs as a function of change in (a) single-session change in running distance; (b) acute:chronic workload ratio (ACWR); and (c) week-to-week ratio. On the x-axis, a value of 1 represents no change, a value below 1 represents regression and a value above 1 represents progression in kilometres.

following: (1) the prospective study design, which includes an up to 18-month follow-up period allowing for the assessment of exposure information prior to outcome data; (2) the inclusion of objectively-measured time-varying exposure rather than averaged information on running data; and (3) recruitment of English-speaking runners from more than 87 different countries facilitated via a productive partnership with Garmin.[22]

Limitations

The following limitations are noted: (1) validity of the self-reported injury outcomes; (2) use of running distance as an exposure and the use of 'binned' exposure states; (3) the analytical approach including generalisability; and (4) causal assumptions. Injury assessment, origin (overuse vs traumatic) and location were self-reported, which carries information bias[45] though the validity of self-reported injury locations is found to be high.[46] Self-reporting running-related injuries depends on the injury definition used, which in this case did not require complete stoppage. Further, runners may struggle to classify injuries as overuse or traumatic, possibly inflating the number of traumatic injuries.

The use of running distance to calculate changes in running load should be considered, although GPS-measured distance is superior to self-reported running distance.[25 26 47] While running distance is a widely understood metric, especially among runners, it may not be the optimal measure of load. Another consideration is the approach used to analyse data. Other risk factors beyond changes in training load, such as previous injury, absolute running distance (eg, weekly mileage), age, diseases/musculoskeletal conditions and BMI were not included as effect measure modifiers as recommended due to low injury numbers, raising the risk of spare data bias.[48] Therefore, it was not possible to provide specific advice for different subgroups of runners. Finally, the causal assumptions underpinning the study should be carefully considered. While confounders such as sex, BMI and prior injuries were included, the cause of running-related injury is multifactorial involving various exposures.[23 25] The observational nature of the study design limits the robustness of the causal claims regarding injury prevention. To evidence-base the preventive effect of recommending runners to stay below a 10%-spike threshold to reduce injury risk, randomised trials or novel approaches such as target trial emulation should be pursued in future work.[49]

CONCLUSION

This study has revealed that a significant dose-response relationship exists between changes in single-session distance and running-related injuries in a cohort of 5205 adult runners, predominantly males from Europe and North America. Notably, a spike>10% in single-session running distance significantly increased the rate of overuse running-related injuries, with the risk sharply rising when the distance more than doubled. Spikes in the ACWR, traditionally used in research and by industry, and spikes in the week-to-week ratio approach were not associated with an increased injury rate. Coaches and healthcare professionals, including primary care physicians, allied health services and orthopaedic specialists may consider using a session-specific cut-off below 10% to ensure the health and safety of runners and patients.

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Acknowledgements Garmin is greatly acknowledged for the assistance with recruiting study participants. Peter Lübben assited with graphical layout of Figure 1, 2 and 3.

Contributors The study was designed in collaboration between all authors. Data collection was completed by NSS and RON. The analyses were carried out by JSBF, ETP and SS. The results were interpreted by all authors. RON, AH and JSBF wrote the first draft of the manuscript, which was subsequently revised for important intellectual content by the remaining authors. All authors approved the final version of the manuscript prior to submission. RON is the guarantor.

Funding The study is supported by unconditional grants from Aarhus University Research Foundation (grant number: AUFF-E-2015-FLS-9-9) and the Danish Rheumatism Association to RON (grant number: R160-A5157). The contribution made by AH was supported by an Australian Research Council DECRA Fellowship: DE240100095. Garmin and these funders had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct or reporting, or dissemination plans of this research. Viewpoints and opinions from runners published in the scientific literature, the authors' experience as runners and experienced running injury researchers, as well as the 10% rule, collectively served as inspiration for this work.

Patient consent for publication Not applicable.

Ethics approval Permission from research ethics committee was not required as per The Danish Act on Research of Health Projects, Section 14, no.2. The Danish Data Protection Agency approved the study (reference number 2015-57-0002).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement According to the informed consent, no data can be shared outside Aarhus University.

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