



Received: 29 November 2018
Accepted: 22 February 2018
First Published: 01 March 2019

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Reviewing editor:
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ORTHOPEDICS | RESEARCH ARTICLE

Incidence and characteristics of acute and overuse injuries in elite powerlifters

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Abstract: The aim of this study was the analysis of incidence and type of injury in German elite powerlifters. A total of n = 57 competitive athletes of the German powerlifting federation completed a retrospective survey regarding acute and overuse injuries.

With 224 total injuries, a mean incidence of 1.51 per 1.000 h or 0.49 per year was calculated. Most injuries affected the lower back (20.5%), elbow (11.2%), pelvic region (10.3) and the shoulder (9.8%). Regarding the type of injury acute inflammation (25.9%), muscle strains/sprains (20.5%) and skin lesions (13%) dominated. The mean incidence significantly declined with increasing age and training experience of the athlete. Athletes using a bench press shirt and various regenerative methods like sauna or swimming also showed decreased injury rates. There was no significant correlation between body weight, height or gender and injury incidence.

Compared to other sports, the incidence of injuries and overuse syndromes is still low in powerlifting. Nonetheless, appropriate strategies in training, equipment, prevention and regeneration should be employed to protect the athlete from injury.

Subjects: Orthopedics; Sports Medicine; Physiology

Keywords: powerlifting; weightlifting; bench press; injury; overuse injury; strength training

1. Introduction

Powerlifting consists of three different exercises, the squat, bench press and deadlift. In each lift, the athlete has three attempts to reach his maximum weight for one repetition. It evolved in the 1950s in the USA from classic weightlifting with the first official championship in 1965 (Kraemer et al., 2017)(Unitt, 2018). The three lifts were formerly used as assistance exercises to improve



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Thomas Reichel The research activities of our group include a broad spectrum from basic research to clinical trials in trauma, hand, plastic and reconstructive surgery. In our department for sports traumatology we focus on research regarding injury prevention, treatment and rehabilitation in amateur to elite athletes of any sport.

PUBLIC INTEREST STATEMENT

Powerlifting is a strength sport consisting of the squat, bench press and deadlift. With gaining popularity of powerlifting and strength training in general around the world there is only limited data regarding injuries in strength sports. We present data showing injury incidence and distribution in elite athletes as well as influencing factors like training periodization, powerlifting equipment and restorative methods. This work further shows directions of future research to prevent acute and overuse injuries in strength sports.

weightlifting performance (Suchomel, Nimphius, Bellon, & Stone, 2018). They transformed into a distinct sport with official competitions. With rising popularity, powerlifting has been established as part of the World Games since 1981.

Training in powerlifting demands development of maximum force production, usually by increasing speed- and maximum strength. Therefore, the active and passive elements of the musculoskeletal system have to withstand high forces. To understand and prevent acute and chronic injuries a thorough analysis of sport-specific injury mechanisms and possible contributing factors is necessary.

To this date, there are few published articles regarding injuries specific to powerlifting (Aasa, Svartholm, Andersson, & Berglund, 2017; Goertzen, Schöppe, Lange, & Schulitz, 1989; Haykowsky & Warburton, 1999; Keogh & Winwood, 2017; Siewe et al., 2011a; Willick et al., 2015). Our main goal in this study was to examine possible relations between sport-specific equipment in competitive powerlifting and resulting in acute or chronic overuse injuries. Furthermore, we examined the influence of different preventive and regenerative strategies like stretching, warming up, sauna, training intensity and training volume on injury incidence.

2. Material and methods

Data acquisition was performed by an anonymous retrospective survey, which was handed out to eligible athletes online and in print. The response rate was moderate (16%) due to the time-consuming survey (350 athletes were contacted, 173 returned the survey with only 57 participants completing the survey, 116 participants only partially completed the survey). Informed consent was obtained by every participant. The survey consisted of three topics, regarding demographic and anthropometric, training- or competition related and injury-related facts. For higher value and comparability, only active, competitive athletes of the German powerlifting federation (BVDK) were surveyed. This federation holds competitions and championships according to the rules of the international powerlifting federation (IPF) (Bundesverband Deutscher Kraftdreikämpfer e.V., 2012). Other federations with different regulations and basic rules were not included. We used a Likert-scale (1 = never, 2 = less than once a month, 3 = once to thrice a month, 4 = at least once a week, 5 = every training) to assess the frequency of training modalities or use of equipment. We also distinguished the different training phases in the preparatory phase (A), competition phase (B) and the competition itself (C). Impairment in training due to injury was assessed using a numeric scale from 1 to 10 (with 1 being no impairment, 10 being maximum impairment). A statistical and graphic analysis was performed with SPSS for Windows in the current version 19.0 (SPSS Inc., Chicago, Illinois, USA) and Microsoft Excel 2007 (Microsoft Corp., Redmond, Washington, USA). To test for significance, depending on the variables bivariate correlation test after Pearson/Spearman and Mann-Whitney-U-Test were used. Level of significance for all tests was p -value < 0.05 (alpha 5%). Values of significance (p) and the coefficient of correlation (r) were rounded to three decimals.

3. Results

A total of 57 athletes from 40 different clubs, all members of the German powerlifting association, were included in the survey. Mean age was 33.4 ± 11.2 years, mean height 176.5 ± 5.7 cm and mean total body weight were 96.7 ± 23.5 kg. Only 5.3% of athletes were female. Athletes had a mean training experience of 14.8 ± 8.7 years, with mean-specific powerlifting training experience of 9.3 ± 7.1 years. Mean competitive experience was 8.2 ± 6.6 years. Annual frequency of competitions was 5.6, consisting of 2.3 single bench-press competitions, 2.2 full powerlifting meets and 1.1 single dead lift competitions. Athletes trained a mean of 3.4 times per week for a mean of 108.6 min per training (Table 1).

Only 40.4% of the athletes performed a general warm-up before training, only 38.6% performed stretching prior to training, 36.8% performed stretching after training and only 12.3% cooled down (Figure 1).

Hypertrophy training (repetition range 4–12) was performed mostly in the preparatory phase (3.79) and training for maximum strength in competition phase (4.28). Training of speed strength using

Table 1. Demographic table of participants

| Demographics | Mean | SD |
|---|-------------------|------|
| Age (y) | 33.4 | 11.2 |
| - Gender | 54 male, 3 female | |
| Height (cm) | 176.5 | 5.7 |
| Body weight (kg) | 96.7 | 23.5 |
| Training experience (years) | 14.8 | 8.7 |
| Specific powerlifting training (years) | 9.3 | 7.1 |
| Competitive experience (years) | 8.2 | 6.6 |
| Training frequency (times per week) | 3.4 | 0,8 |
| Competition frequency (times per year) | 5.6 | 2.5 |
| - Single bench press competitions (t/y) | 2.3 | 2.1 |
| - Single deadlift competitions (t/y) | 1.1 | 1.0 |
| - Full powerlifting competition (t/y) | 2.2 | 1,9 |

Figure 1. Modalities for warm-up/cool-down.

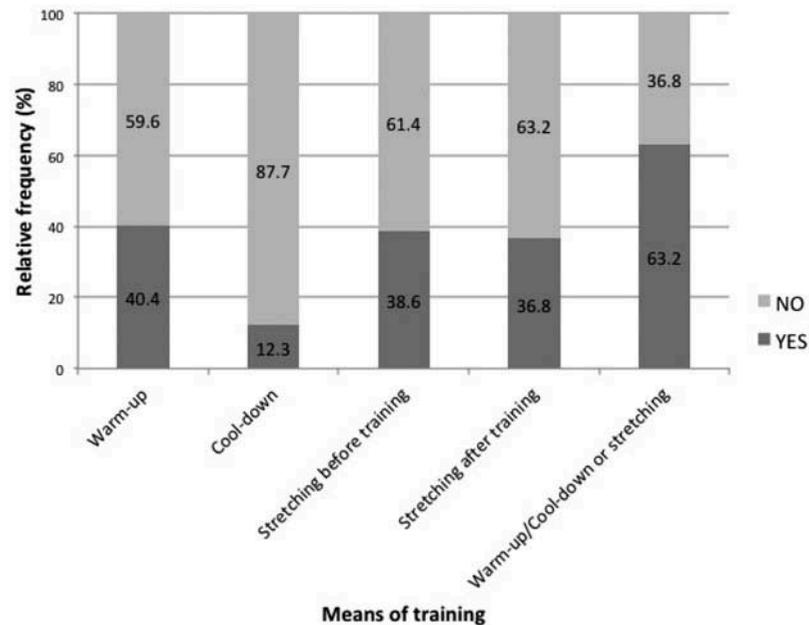
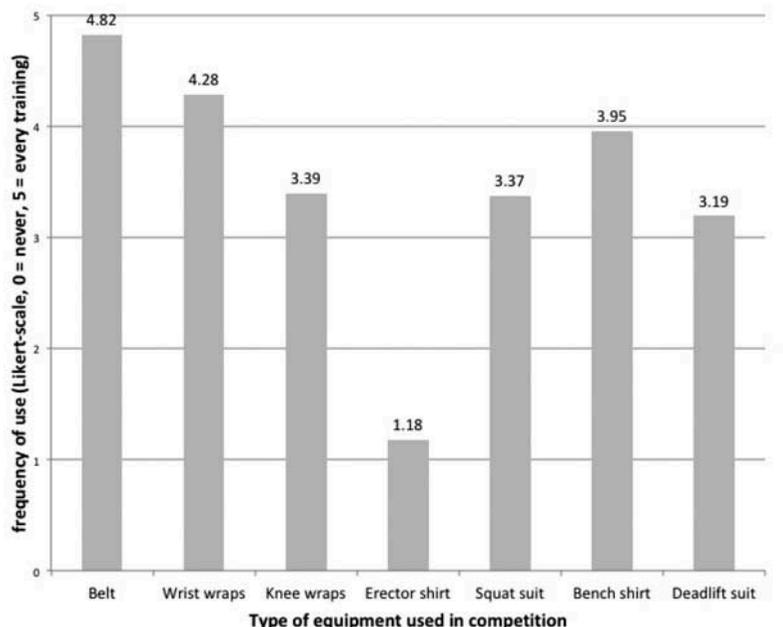


Figure 2. Possible setup for bench presses with band tension or chains, bench press boards and a box for box-squats.



Figure 3. Equipment used in competition (1 = never to 5 = every training).



dynamic methods was performed in equal frequency during preparatory (2.81) and competition phase (2.77). Regarding powerlifting specific equipment and exercises (Figure 2) the most common were board pressing (A: 2.16; B: 2.72), chains or elastic bands (A: 2.26; B: 2.37) and box squats (A: 2.07; B: 1.84). The frequency of equipment usage (Figure 3) was evaluated using the same scale. Usage of equipment increased in a linear fashion leading up to the competition: belt (A: 3.09; B: 3.98; C: 4.82), wrist wraps (A: 3.23; B: 3.77; C: 4.28), knee wraps (A: 1.82; B: 2.74; C: 3.39), squat suit (A: 1.35; B: 2.61; C: 3.37), bench shirt (A: 1.32; B: 2.68; C: 3.95) and deadlift suit (A: 1.23; B: 2.16; C: 3.19). An erector shirt was seldom used (A: 1.04; B: 1.12; C: 1.18).

During training sessions, only 50.9% of athletes were supervised and supported by certified trainers. In total 35.1% owned an official trainer certification. The most important source for acquiring knowledge about powerlifting exercises, methods and technique were experienced training partners in 80.7%, internet research in 70.2% and specific literature in 68.4% cases.

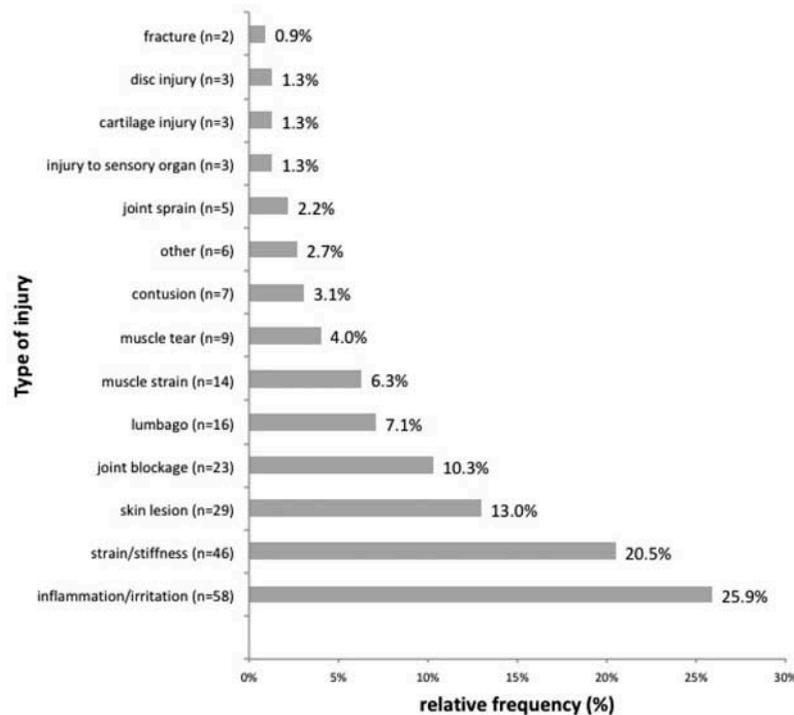
Performance of a different kind of sport leisure activities was reported in 56.1% cases. Biking (26.3%) and jogging (12.3%) and various ball sports (10.5%) were the most common. Only 15.8% of athletes implemented any kind of sensorimotor training in their workouts.

Regarding methods to enhance recovery, sleep (82.5%), nutrition and nutritional supplements (64.9%), stretching and sauna (42.1% each) were mostly mentioned. A high percentage (82.5%) of athletes stated they took care to adapt their nutrition to the needs of powerlifting.

Anti-inflammatory drugs or pain medication were used in 43.8%, and about a fourth of these lifters took pain medication to alleviate pain from an injury.

The total number of 224 acute injuries (53.1%) and chronic overuse injuries (46.9%) were categorized according to location and type. Acute inflammation or irritation (25.9%), muscle strains and spasms (20.5%), skin lesions (13%) and joint dysfunctions (10.3%) were most common (Figure 4). Most of these injuries affected the upper extremity (41.5%), followed by the lower extremity (30.4%), spine (25%), head and neck (3.1%). The areas affected the most were the lower back (20.5%), elbow (11.2%), pelvis and sacroiliac joint (10.3%) and the shoulder (9.8%). Regarding the cause of these injuries athletes mentioned too high intensities, wrong technical performance and lack of concentration.

Figure 4. Distribution and incidence of injuries.



Athletes of higher age (>30 years) sustained significant less injuries ($P = 0.004$; $r = -0.373$) than younger athletes. Higher experience (measured in years) in training ($p = 0.000$; $r = -0.373$) and competition ($p = 0.002$; $r = -0.422$) resulted in a decreased injury rate.

There were no significant correlations regarding gender, height or weight. With regard to competition, powerlifters were injured more often in the lower extremity ($p = 0.044$; $r = -0.282$) than lifters in the bench press or dead lift only competitions. Athletes using a bench press shirt in the competition show a significantly lower rate of injury of the upper extremity ($p = 0.046$; $r = -0.256$).

Warming up, cooling down, stretching or proprioceptive training had no influence on the rate of injury. Swimming as a leisure activity was correlated with fewer injuries ($p = 0.027$, $r = -0,288$). The regular sauna was also significantly correlated with a lower rate of injury ($p = 0.017$, $r = -0,318$). Good sleep was also correlated with fewer injuries ($p = 0.008$, $r = -0,352$).

Regarding training periodization, it was apparent that athletes performing in repetition ranges above 12 in their competition phase sustained significantly more injuries ($p = 0.048$; $r = 0.263$).

Treatment of one or more injuries was physiotherapy in 56%, medication was used in 50%, operative treatment was carried out in 8%, and a total of 42% remained untreated.

As a consequence of an injury or overuse syndrome 36% of athletes had to refrain from training for 1–7 days, 28% for 1–2 weeks and 22% for 2–4 weeks. In addition, 22% omitted one or more of the power lifts due to injury for 1–3 months.

Movement or training impairment because of an injury caused by powerlifting was a complaint in 64% of injured athletes. Here a moderate impairment on a scale from 1 to 10 was found (5.36). Chronic pain was stated by 24% of the athletes, with a small to moderate intensity of 3.43. More than one third was located in the shoulder region (35.7%) and almost another third was located in the lower back (28.6%).

4. Discussion

As data acquisition regarding injuries in this study was done during active participation in competition, there was a significant number of lifters (8.7%) sustaining an acute or overuse injury, in accordance with previous research (Haykowsky & Warburton, 1999; Keogh, Hume, & Pearson, 2006; Raske & Norlin, 2002; Winwood, Hume, Cronin, & Keogh, 2014). Due to longer observation time and the possibly difficult retrospective design the injury incidence of 1.5 per 1,000 h was lower than the mean incidence in most of these already published studies that showed injury incidences ranging from 2,6 to 5,5 per 1000 h (Keogh et al., 2006; Raske & Norlin, 2002; Winwood et al., 2014). Only Siewe et al. reported an even lower incidence with 0,3 per 1000 h in a similar cohort of German powerlifters (Siewe et al., 2011a). Regarding the number of participants, gender distribution, mean age, training- and competitive experience, type and localization of injury and treatment, results were similar to previously published and mentioned research. High incidence of skin lesions, mainly skin abrasions, caused by the wearing of specialized equipment or direct contact of the barbell to the legs during deadlifts was striking. Usage of baby powder or knee long socks conforming to competition rules is an easy way to lessen or abolish these injuries.

While previous studies (Keogh et al., 2006) found no correlation between age and rate of injuries in powerlifting and even a higher incidence in strongman athletes of higher age (Winwood et al., 2014), in our collective powerlifters of higher age sustained significantly less injuries. Despite the logical assumption that coordination and conditioning decrease with higher age, the higher experience in training and competition of older athletes led to a lower rate of injuries. Through experience older athletes probably optimize load and volume management in training preventing some injuries. Maybe they even are better at estimating their attempts in training and competition, taking less risk with unsuccessful or very demanding attempts.

With regard to competition, powerlifters were injured more often in the lower extremity than lifters in the bench press or deadlift only competitions. An assumption would be that the additional training volume regarding the lower extremity with training the squat contributes to this difference. Research in rugby players (Gabbett, 2010) and youth athletes (Post et al., 2017) reported increased injuries with increasing training volume, but so far there is no known threshold or specific volume that determines injury risk, probably because the response of any athlete to a given training volume is highly individual, can change over time and depends on multiple factors like anthropometry, level of competition, physiology and psychology (Slobounov, 2008).

Swimming as a leisure activity was correlated with fewer injuries, although it is unclear which factors contributed to this reduction. Regular sauna was also significantly correlated with a lower rate of injury, thereby confirming the regenerative effect on the musculoskeletal system by the supposed mechanisms of increased skin- and muscle-blood flow, faster degradation of products of metabolism and muscle as well as up- and downregulation of a multitude of genes specific to muscle hypertrophy and atrophy (Hannuksela & Ellahham, 2001; Leppäluoto et al., 1986; McGorm, Roberts, Coombes, & Peake, 2018).

Good sleep was also correlated with fewer injuries ($p = 0.008$) although no further objective analysis of sleeping parameters like duration and quality was possible. The importance of sleep in recovery and restitution of physical and cognitive performance is well known (Godfrey, Madgwick, & Whyte, 2003; Walker & Stickgold, 2005; Walters, 2002).

The items nutrition, usage of pain medication, support by a coach and studying were not correlated with fewer injuries.

Regarding training periodization it was apparent that athletes performing in repetition ranges above 12 in their competition phase, classified as strength-endurance training (Zatsiorsky & Kraemer, 2006), sustained significantly more injuries ($p = 0.048$; $r = 0.263$); we assume the usually performed training of maximum strength in low repetition ranges from 1 to 3 in contest preparation

was negatively influenced by concurrent training of strength-endurance. Diminished adaptation to the high to maximum strain in competition could contribute to a higher risk of injury. It is known, that training leading up to a competition should be increasingly sport-specific, as different training means cause different physiological adaptations; training load or intensity is one main determinant, influencing not only power output and kinematics of the trained movement, but also neuromuscular and structural adaptations (Schoenfeld, Contreras, Vigotsky, & Peterson, 2016; Schoenfeld, Peterson, Ogborn, Contreras, & Sonmez, 2015; Verkhoshansky & Siff, 2009; Whitting, Meir, Crowley-McHattan, & Holding, 2016). Therefore, choosing the right training load and repetition ranges with correct periodization could reduce injuries by improving adaptation to the sport specific task. Further research is needed to prove this theory, although it is widely practiced by strength coaches worldwide.

Athletes using a bench press shirt in competition show a significantly lower rate of injury of the upper extremity in our collective ($p = 0.046$; $r = -0.256$). The reasons for this besides the proposed protective and load reducing the effect of the equipment could be differences in technique, periodization and volume of training in athletes with protective gear. Two published studies showed a direct effect for grip width (Wagner, Evans, Weir, Housh, & Johnson, 1992) and the use of a bench shirt (Silver, Fortenbaugh, & Williams, 2009) on bar path, warranting further research to elucidate the correlation to injury risk. Maybe a shorter bar path with less shoulder abduction and a different force curve in a bench shirt can decrease load on joints and connective tissues.

More frequent performance of the deadlift was correlated to more injuries in the lower back and sacroiliac joint ($p = 0.002$; $r = 0.398$) which seems plausible knowing the high hip torque and lumbar shear force documented in research (Brown & Abani, 1985; Cholewicki, McGill, & Norman, 1991; Escamilla et al., 2000). Athletes using front squats more frequently, on the other hand, showed more injuries to the knee ($p = 0.047$; $r = 0.266$) and thigh ($p = 0.006$; $r = 0.364$). This pattern is plausible, as the more vertical orientation of the torso during the front squat demands the knee to travel forward to keep balance. The resulting long lever, more acute knee angle and therefore higher torque on the knee joint increase the strain on the joint itself as well as the quadriceps muscle (Hartmann, Wirth, & Klusemann, 2013; Swinton, Lloyd, Keogh, Agouris, & Stewart, 2012; Wretenberg, Feng, & Arborelius, 1996).

5. Perspectives

Powerlifting and other strength sports like strongman or CrossFit are becoming increasingly popular with a rising number of athletes including both genders and different age groups. The high demands on the musculoskeletal system create a risk of acute and chronic injuries. Our study confirmed the relatively low injury rate seen in previously published research. To prevent these injuries in the future we examined elite powerlifters in Germany and found correlations between usage of specific powerlifting equipment, restorative methods and training structure. This data demands further research in this area to determine factors that could decrease the injury risk and its negative impact on performance and athletes quality of life.

6. Conclusion

In this study, we were able to gain new insights into the influence of powerlifting equipment, preventive and regenerative methods as well as training periodization on the rate of acute and overuse injuries in powerlifting. To analyse the injury mechanisms and causative factors further, future studies should focus on prospective designs to evaluate and manipulate different training and competition variables. In addition, a higher number of participants would be beneficial to increase the statistical weight of the results.

Further, more detailed analysis of different aspects in training periodization, methods, volume, exercise selection, equipment use, preventive and regenerative methods and lastly anthropometric measurements of athletes could be the foundation for a better understanding and consequently validation of causative factors for injuries in powerlifting as well as to validate proposed concepts to reduce these injuries in high risk areas like the lower back and shoulder region (Escamilla et al.,

2000; Fees, Decker, Snyder-Mackler, & Axe, 1998; Green & Comfort, 2007; McGill, 1998; Reeves, Laskowski, & Smith, 1998).

It may also be important to collect data regarding the timing of injuries (preparatory phase, pre-competition-phase).

Future studies should develop an optimized set of preventive exercises and lifestyle recommendations individualized to the relevant preconditions and risk factors of each athlete to reduce or prevent acute and overuse injuries.

Funding

This publication was funded by the German Research Foundation (DFG) and the University of Wuerzburg in the funding programme Open Access Publishing.

Competing interests

The authors declare no competing interests.

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Citation information

Cite this article as: Incidence and characteristics of acute and overuse injuries in elite powerlifters, Thomas Reichel, Martin Mitnacht, Annabel Fenwick, Rainer Meffert, Olaf Hoos & Kai Fehske, *Cogent Medicine* (2019), 6: 1588192.

Correction

This article has been republished with minor changes. These changes do not impact the academic content of the article.

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