

# CONCERNS ABOUT STRENGTH TESTS IN GYMNASTICS: A SYSTEMATIC REVIEW

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## Abstract

*This study aims to analyze the specialized literature on the protocols, instruments, and techniques used to train and assess strength in gymnastics practitioners or athletes who are represented by the International Gymnastics Federation (Fédération Internationale de Gymnastique – FIG). The systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Systematic searches on the PubMed, Web of Science, Scopus, LILACS, SciELO, and SPORTDiscus databases were conducted using the following keywords: “assessment,” OR “measurement,” OR “evaluation,” AND “child\*,” OR “young,” OR “adolesc\*,” AND “athlete\*,” OR “practitioner,” OR “gymnast\*,” AND “gymnastic\*,” OR “trampoline,” AND “muscle strength,” OR “muscle power,” OR “strength,” OR “power,” OR “concentric,” OR “performance,” OR “explosive strength,” OR “motor tests”. Studies included in this review address the assessment and training of strength in gymnastics or athletes. Fourteen studies assessing the physical capacity strength in practitioners or gymnastic athletes were the basis of this systematic review. These articles describe low-cost, easy-to-apply protocols and instruments performed in the training gym. The included articles focused on assessing the strength level of adolescent male and female practitioners or athletes for talent selection and detection, as well as lesion reduction. Despite the benefits of strength training, such as better performance and fewer injuries, in general, strength is not regularly assessed. Only studies encompassing artistic and rhythmic gymnastics were found.*

**Keywords:** *gymnastic, trampoline, muscle strength, motor tests.*

## INTRODUCTION

According to the International Gymnastics Federation (*Fédération Internationale de Gymnastique – FIG*) gymnastics modalities include acrobatic gymnastics, aerobic gymnastics, artistic gymnastics for women, artistic gymnastics for men, rhythmic gymnastics, trampoline

gymnastics, gymnastics for all, as well as parkour. Each sport style has its own previously defined technical regulation and punctuation code (rules) (FIG, 2021). Jumping movements, acrobatics, spins and precise landings are common motor demands in gymnastics sport modalities (Abuwarda, 2020; Hall, Bishop & Gee, 2016). Therefore, gymnastics performance requires substantial flexibility, strength,

power, coordination, rhythm, agility, and endurance (Batista, Garganta & Ávila-Carvalho, 2017; Malina et al., 2013; Sleeper, Kenyon, Elliott & Cheng, 2016; Russo et al., 2021).

In the context of gymnastics sport characteristics, performing routines is related to important requests in terms of muscle strength, power, and endurance (Kerr, Heyden, Barr, Klossner & Dompier, 2015). Indeed, muscle strength and power are essential to support increasing physical performance, as well as motor skills improvement (Cooper et al., 2015). Considering competitive circumstances, these muscle characteristics are important conditions to reach high levels of athletic practice in artistic (AG) and rhythmic gymnastics (RG), in addition to being involved with jumping and pivot movements (Batista, Garganta & Ávila-Carvalho, 2017; Mkaouer, Hammoudi-Nassib, Amara & Chaabène, 2018; Hammoudi-Nassib, Mkaouer, Riahi, Wali & Nassib, 2020). Indeed, physical fitness related to health and/or sport performance is directly associated with muscle strength improvement (French et al., 2004), and measuring muscle strength has been considered an important performance parameter in sports (Mohamed, 2011).

Based on this, training programs should include prescribed specific training and control actions to improve sport performance as organizational strategy for both aerobic and anaerobic demands (Batista, Garganta & Ávila-Carvalho, 2017; French et al., 2004). Gymnastics training methods and analyses need to be better clarified since they have been used not only for talent detection but also for improving athletic performance (Batista, Garganta & Ávila-Carvalho, 2017; Sleeper, Kenyon & Casey, 2012; Sleeper, Kenyon, Elliott & Cheng, 2016). Previously, while some studies documented biomechanical aspects (Kochanowicz et al., 2016; Shärer, Haller, Taube & Hubner, 2019), other investigations reported performance skills associated with movement demands on

gymnastics apparatus (Aleksic-Veljkovic, Djurovic, Dimic, Mujanovic & Zivivic-Markovic, 2016; Andreyeva, 2013). Regarding strength assessment in gymnastics modalities, the Gymnastics Functional Measurement Tool (GFMT) (USA Gymnastics, 2014; Sleeper, Kenyon, Casey, 2012; Sleeper, Kenyon, Elliott & Cheng, 2016), the Talent Opportunity Program (TOPS) (Bacciotti, Baxter-Jones, Gaya & Maia, 2019) and FIG analyses (Batista, Garganta & Ávila-Carvalho, 2019; Mkaouer, Hammoudi-Nassib, Amara & Chaabène, 2018) are the most used analytical methods, as well as dynamometry tests (Russel, Quinney, Hazlett & Hillis, 1995) and jump tests (French et al., 2004; Dobrijevic, Moskovljevic, Markovic & Dabovic, 2018).

However, the presented methods have been mainly used for identifying and selecting sport talents. Although monitoring training effects is important in gymnastics, the description of methods and respective uses are yet to be defined (Bacciotti, Baxter-Jones, Gaya & Maia, 2019). Indeed, assessing athletic performance in gymnastics is a fundamental step to indicate progress and potential for practice, hence the importance of knowing which tests are most applied and useful to trainers for strength training. Therefore, this study aims to analyze protocols, instruments, and techniques used to train and assess strength in gymnastics practitioners or athletes who are represented by the FIG.

## METHODS

The systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the protocol was registered with PROSPERO.

The following databases were used: PubMed, Web of Science, Scopus, LILACS, SciELO, and SPORTDiscus. The following search terms were used: “assessment,” OR “measurement,” OR “evaluation,” AND “child\*,” OR “young,”

OR “adolesc\*,” AND “athlete\*,” OR “practitioner,” OR “gymnast\*,” AND “gymnastic\*,” OR “trampoline,” AND “muscle strength,” OR “muscle power,” OR “strength,” OR “power,” OR “concentric,” OR “performance,” OR “explosive strength,” OR “motor tests”.

Original articles published in English or Portuguese until March 2021 were eligible for inclusion. Additionally, the authors also considered studies that: sampled both sexes; had at least one of the modalities represented by the International Gymnastics Federation (*Fédération Internationale de Gymnastique* – FIG); assessed muscle strength in gymnasts; included clear description of methods and instruments, and/or were performed at the training site. Studies were excluded if the results were not stratified by sex; published after March 2021, or had a sample composed by elderly subjects, subjects with physical or mental disabilities, as well as those that did not aim to assess strength as part of conditioning. The bibliography of each study included was also screened by title to identify any additional studies suitable for gathering background information.

Abstracts using the terms and bases described above were independently reviewed by two authors who selected the studies according to their relevance regarding the subject that met all the inclusion criteria. Both researchers compared the selections and addressed the identified differences with the senior author input. Each article was then reviewed in its entirety by one or two co-authors, relevant information was extracted, and discrepancies were solved by discussion between the researchers. EndNote was used as a search and selection manager.

## RESULTS

The article selection process is detailed in the flowchart (Figure 1). In general, 8240 studies were identified, out of which 25 remained after removing duplicates and

reading titles and abstracts. After full reading, 11 articles were removed for not meeting the inclusion criteria. Finally, 14 articles met all the criteria and were used as the basis for this systematic review.

In this study the results are presented in tables. Table 1 presents a summary of eligible studies, extracting information on authors, study design and year, gymnastic modality, sample characteristics and country, capacity surveyed, body segments, and strength tests. Table 2 shows information regarding training techniques, modality, and authors and year.

The titles of the evaluated works mentioned at least one of the types of gymnastics constituting the FIG programs, with studies addressing artistic gymnastics (male athletes: 3; female athletes: 6) and rhythmic gymnastics (n=5) being predominant. The search did not produce any studies on other types of competitive gymnastics.

Regarding the characteristics of the sample, most of the studies were composed of elite gymnasts (n=6), followed by comparative studies between elite and non-elite groups (n=4), in the age range of 6 to 22 years (French et al., 2004; Sleeper, Kenyon & Casey, 2012). Most studies used a cross-sectional design (n=8), and six had a longitudinal design.

For the assessments of muscle strength, only studies that were carried out at the training site were selected to minimize the cost and take advantage of the practical context. In the analysis of physical fitness and/or strength, the most cited physical skills were strength (isometric, dynamics, resistance, and explosive; 100% of selected studies), flexibility (42.8%), speed (21.4%), balance (14.2%) and agility (7.1%), of upper and lower limbs, highlighting Russo et al. (2020) emphasizing AG and RG. Regarding the tests used to assess muscle strength, there is a predominance of vertical jumps (countermovement and squat jumps) (n=6), FIG battery (n=3), Gymnastics Functional

Measurement Tool (GFMT) (n=2), and the Talent Opportunity Program (TOPS) (n=1).

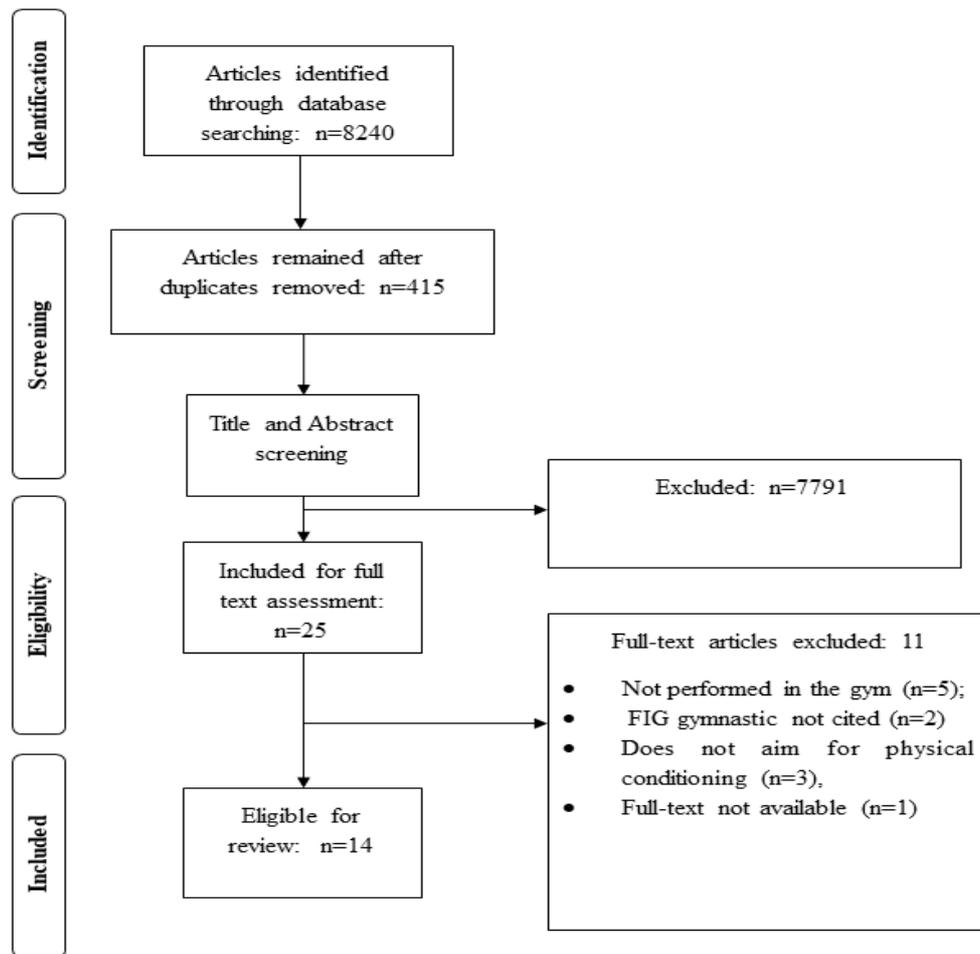


Figure 1. Flow chart describing the identification of articles related.

Table 1  
Summary of the studies that assess strength in gymnasts.

AUTHORS, STUDY DESIGN AND YEAR	GYMNASTIC MODALITY	SAMPLE AND COUNTRY	CAPACITIES ASSESSED	BODY SEGMENTS	STRENGTH TESTS
French, et al. Longitudinal (2004)	Artistic Gymnastics (AG)	20 female gymnasts Age: 18-22 years Country: EUA	Peak power output and time to peak power	Lower limbs	2 tests: Two vertical jump protocols (countermovement and squat jumps)
Douda, et al. Longitudinal (2007)	Rhythmic Gymnastics (RG)	Sample: 152 female 71 rhythmic gymnastics (RG) athletes 81 non-athletes (control) Age: 8-17 years	Speed, muscular strength, jumping ability, explosive power, and flexibility	Lower limbs	2 tests: Standing long jump Countermovement jump test

Country:  
Greece

Mohamed. Longitudinal (2011)	Artistic gymnastics (AG)	Sample: Two groups, an experimental group consisting of (7) elite female gymnasts, and a control group consisting of (4) elite gymnasts Age: 11 ± 1,36 years Country: Egypt	Strength, power and performance level	Legs	4 tests: Vertical jump test Seated medicine ball throw Leg strength back strength by dynamometer Dynamic strength test, Performance levels of landing in floor exercise
Sleeper, Kenyon, Casey. Cross-sectional (2012)	Artistic gymnastics (AG)	Sample:105 competitive female gymnasts Age: 6-18 years Country: EUA	Strength, power, upper and lower extremity power, abdominal strength, hip flexor strength, flexibility, and grip strength	Upper and lower limbs and trunk	Battery tests GFMT 7 tests: Rope climb test Jump test Hanging pikes test Over-grip pull-up test Push-up test 20-yard sprint test Handstand test
Gateva. Cross-sectional (2013)	Rhythmic gymnastics (RG)	Sample: 120 rhythmic gymnasts Age: 10-19 years Country: Bulgária	Strength abilities	Abdomen, back and legs	3 tests: Sit ups Back strength Vertical jump
Hall, Bishop, Gee. Longitudinal (2016)	Artistic gymnastics (AG)	Sample: 20 female gymnasts Age: 12,5 ± 1,67 years Country: United Kingdom	Explosive power	Lower limbs	1 test: Countermovement jump test
Sawczyn, et al. Longitudinal (2016)	Artistic gymnastics (AG)	Sample: 24 male gymnasts Age: 12-13 years Country: Poland	Maximum static strength (isometric) and dynamic strength	Upper limbs	2 tests: Maximum static strength (isometric Fmax peak) Dynamic (peak of force) established based on the ergometer and ergo power

					dynamometric system (Globus, Italy)
Sleeper, et al. Cross-sectional (2016)	Artistic gymnastics (AG)	Sample: 83 male gymnasts Age: 7-18 years Country: EUA	Flexibility, strength, power, agility and balance	Multiple body segments	Battery tests MGFMT 6 tests: Rings hold test Vertical jump test Hanging pikes test Over-grip pull-up test Handstand push-up test Handstand test
Batista, et al. Cross-sectional (2017)	Rhythmic gymnastics (RG)	Sample: 68 rhythmic gymnasts Age: 11,7 ± 0,6 years Country: Portugal	Resistance strength, muscular endurance and explosive strength	Abdomen and legs	FIG test battery 6 tests: Front power kick Back power kick Partial trunk elevations Partial curl-ups Rope skipping Vertical jump test
Dobrijevic´ et al. Longitudinal (2018)	Rhythmic gymnastics (RG)	Sample: 47 rhythmic gymnasts Age: 7-9 years Country: Serbia	Explosive strength	Legs	2 tests: Countermovement jump test Standing long jump test
Mkaouer, et al. Cross-sectional (2018)	Artistic gymnastics (AG)	Sample: 50 male gymnasts Age: 11,03 ± 0,95 years Country: Tunisia	Strength, flexibility, speed, endurance, and power	Upper and lower limbs and trunk	FIG test battery 4 tests: Double legs circle (on mushroom) V lever (legs to or over vertical) Tucked top planche (body horizontal through shoulder, arms stretched) Back hang scale (body horizontal, legs and arms stretched)
Bacciotti, et al. Cross-sectional (2019)	Artistic gymnastics (AG)	Sample: 249 female gymnasts Age: 9-20 years Country: Brazil	Strength, flexibility and explosive strength	Upper and lower limbs and trunk	TOPS 3 tests: Rope climb Press handstand Leg lift

Batista, et al. Cross-sectional (2019)	Rhythmic gymnastics (RG)	Sample: 164 rhythmic gymnasts Three different levels: Base age 13.5±2.3; 1st division age 13.6±2.1; Elite age 14.8±1.8 years Country: Portugal	Resistance strength, muscular endurance and explosive strength	Abdomen and legs	FIG test battery 6 tests: Front power kick Back power kick Partial trunk elevations Partial curl-ups Rope skipping Vertical jump test
Russo, et al. Cross-sectional (2020)	Artistic gymnastics (AG) and rhythmic gymnastics (RG)	Sample: 45 volunteer female artistic and rhythmic gymnastics Age: 10-12 years Country: Italy	Joints mobility, balance, explosive strength, speed, and endurance	Lower limbs	1 test: Long jump test

Table 2  
*Training techniques used for strength capacity in gymnasts.*

TRAINING TECHNIQUES	MODALITY	AUTHORS / YEAR
Combined conditioning	Artistic gymnastics (AG)	French, et al. (2004) Mohamed (2011)
Increasing training load for specific movements	Rhythmic gymnastics (RG)	Douda, et al. (2007)
Plyometrics	Artistic gymnastics (AG)	Hall, Bishop, Gee (2016)
Specific suspension training	Artistic gymnastics (AG)	Sawczyn, et al. (2016)
Proprioceptive training	Rhythmic gymnastics (RG)	Dobrijevic, et al. (2018)

For the training techniques applied to improve strength, we verified studies targeting upper limbs (n=1) and mostly lower limbs (n=5), using proprioceptive training program (Dobrijevic, Moskovljevic, Markovic & Dabovic, 2018), conditioning combining strength/power/endurance training (French et al., 2004; Mohamed, 2011), program with

increased training load (volume and intensity) of modality specific movements (Douda, Avloniti, Kasabalis & Tokmakidis, 2007), plyometrics (Hall, Bishop & Gee, 2016), or specific suspension training (Sawczyn et al., 2016). However, we observed that eight of the selected works (57.2%) performed only tests to assess and

quantify the strength capacities of gymnasts.

## DISCUSSION

This study aimed to analyze the specialized literature on the protocols, instruments, and techniques used for training and assessing strength in gymnastics practitioners or athletes based on the FIG reports. The studies included in this review provided information about different tests used to measure strength in gymnastic modalities. This information will be discussed below based on the analyses of the results.

In general, the studies were carried out with gymnasts from artistic (9 articles) and rhythmic gymnastics (5 articles). The absence of studies on other types of gymnastics may be associated with their relatively recent inclusion in the FIG (aerobic gymnastics included in 1995; acrobatic gymnastics in 1998; trampoline gymnastics in 1999; and parkour in 2017) (FIG, 2021), or less publicity by the media. After the final reading of the selected works, we found a study addressing strength training in the gymnastics-for-all modality which is not competitive; however, it does not mention the city where the study was carried out (Karagiani, Donti, Katsikas & Bogdanis, 2020).

In general, there is a greater interest in studying elite athletes as researchers seek to identify variables associated with the gymnasts' motor and competitive performance (i.e., speed, agility, flexibility, and balance). Other studies have demonstrated the importance of these variables in gymnastics modalities (Mlsnová, 2016; Dallas, Pappas, Ntallas & Paradisis, 2018; Ceklic & Sarabon, 2021). Specifically for the assessment of muscle strength, only studies that were carried out at the training site were selected in order to minimize the costs and take advantage of the practical context. Thus, the results indicate that the vertical jump and long jump tests were used in most studies. The

benefit of using these tests is associated with cost-effectiveness, especially the easy application and use in the context of practical execution. The specificity of the vertical jump test in connection with gymnasts' performance is highlighted, since coaches, physical education and health professionals use height in the vertical jump to assess their motor performance and the ability to generate muscle strength and power (Teramoto, Cross & Willick, 2016). However, vertical jump analysis is limited in terms of similarity or description of specific movement linked to the modality.

Instead, the test batteries of FIG, GFMT and Talent Opportunity Program (TOPS) were used in 6 studies, as shown in Table 1. The FIG battery is specific to artistic and rhythmic gymnastics and is generally used to identify talent and quantify physical evolution; in addition, it can be applied in local training sites. In general, it consists of assessing strength, flexibility, speed, endurance, and power in the context of AG. Tests for analyzing strength in male artistic gymnastics are double legs circle (on mushroom), V lever (legs to or over vertical), tucked top planchet (body horizontal through shoulder, arms stretched), and back hang scale (body horizontal, legs, and arms stretched) (Mkaouer, Hammoudi-Nassib, Amara & Chaabène, 2018).

In RG, the FIG battery assesses modality-specific motor patterns using elements and body movements that guarantee results in the sporting context (Batista, Garganta & Ávila-Carvalho, 2017; Batista, Garganta & Ávila-Carvalho, 2019). Therefore, it assesses flexibility, balance, strength, power, endurance, and speed (Dias, Aleksandrova, Lebre, Bobo & Fink, 2019) using the front power kick, back power kick, partial trunk elevations, partial curl-ups, rope skipping, and vertical jump test as protocols for measuring strength.

Conversely, the GFMT battery is specific to female and male artistic gymnastics (The Men's Gymnastics

Functional Measurement Tool – MGFMT) and comprises individual tests that are easy to apply, reflect the physical abilities inherent to the modalities with quantitative results and do not require an expert appraiser (Sleeper, Kenyon & Casey, 2012; Sleeper, Kenyon, Elliott & Cheng, 2016). In addition, they help to identify deficits in physical fitness, which can be useful to prevent injuries. The GFMT assesses strength, power, upper and lower extremity power, abdominal strength, hip flexor strength, flexibility, and grip strength (Sleeper, Kenyon & Casey, 2012) using the rope climb test, jump test, hanging pikes test, over-grip pull-up test, push-up test, 20-yard sprint test, and handstand test. The MGFMT evaluates flexibility, strength, power, agility, and balance (Sleeper, Kenyon, Elliott & Cheng, 2016), using the rings hold test, vertical jump test, hanging pikes test, over-grip pull-up test, handstand push-up test, and handstand test.

In women's artistic gymnastics, the TOPS battery of the American Gymnastics Federation has been used as a talent identification tool (Bacciotti, Baxter-Jones, Gaya & Maia, 2019) using the rope climb, press handstand, and leg lift tests. Regarding strength, it is important for gymnast's performance as has been described in previous studies (French et al., 2004; Mkaouer, Hammoudi-Nassib, Amara & Chaabène, 2018; Sawkzyn et al., 2016). However, gymnasts perform exercises repeatedly, in routines that require a great level of not only strength, but also power, and endurance from the body extremities (Kerr, Hayden, Barr, Klossner & Dompier, 2015). Therefore, a complete proceeding of performance evaluation is more applicable to determine sports performance in gymnastics.

On the other hand, most of the sample was composed of elite athletes aged between 6 and 22 years, which may be associated with the moment of peak performance at the age of between 15 and 21 years (Law, Côté & Ericsson, 2008; Longo, Siffredi, Cardey, Aquilino &

Lentini, 2016; Feeley, Agel & LaPrade, 2016). The countermovement jump (CMJ) is most used to predict lower limb muscle power for school-age children (Gomez-Bruton et al., 2019). It demonstrates greater reliability in this specific population (Acero et al, 2011). Furthermore, the vertical jump is also proposed as an important marker of health and quality of life, in addition to its importance in sports, as it is fundamental for the child development (Malina, 2001). Since this age group is still at the beginning of sport specialization, the jump test may be appropriate to evaluate physical skill levels.

This review implies some limitations as only articles published in English or Portuguese (Brazil) do not represent the totality of studies addressing gymnastics modalities. No studies were found that would focus on other modalities of competitive gymnastics included in the FIG programs. However, the study has a great potential, namely: a) considering there is a lack of consensus among researchers, it improves the understanding of the procedures used to assess strength and performance in gymnasts; b) the search could not find reports on the control system of neither training nor assessment, therefore, technicians should perform and share such control for further specific analyses. Thus, the current findings are of interest to sport science practitioners and medical teams who have considered using analytical methods to evaluate and monitor the development of gymnastics performance.

## CONCLUSIONS

Artistic and rhythmic gymnastics are the most studied modalities represented by the FIG and there are more works researching female than male gymnasts. Modality-specific strength assessment protocols proved to be more efficient in measuring general physical abilities in gymnastics. Specific applied training techniques, on the other hand, can

contribute toward better performance and help minimize the risk of injury.

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