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**YOUTH RESISTANCE TRAINING
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YOUTH RESISTANCE TRAINING

Dr Mike Posthumus, PhD

UCT/MRC Research Unit for Exercise Science and Sports Medicine
Department of Human Biology, University of Cape Town
Sport Science Institute of South Africa
Boundary Road, Newlands 7700
South Africa

Tel.: +27 (21) 6504572

Fax: +27 (21) 6507530

Email: mposthumus@mweb.co.za

Dr Mike Posthumus is a research fellow at the UCT/MRC Research Unit for Exercise Science and Sports Medicine, the Department of human biology, Faculty of Health Sciences, University of Cape Town, South Africa.

DEFINITION OF TERMS:

For the purpose of this manuscript, the term “youth” is broadly defined to include all developmental stages of childhood (children) and adolescence (adolescents). “Children” refers to young boys or girls who have not yet developed secondary sex characteristics (approximately up to the age of 11 among girls and 13 among boys). “Adolescents” refers to boys and girls between the childhood and adulthood stages (approximately 12-18 years among girls and 14-18 years among boys). The childhood and adolescence stages are normally separated by the onset of puberty. “Resistance training” refers to the use of any resistive load, including body mass, designed to enhance muscular strength and endurance. The term resistance training is synonymous with other terms such as “strength training”, “weight training” and “weight lifting”.

INTRODUCTION:

Many misconceptions exist regarding the possible risks to children and adolescents participating in resistance training ⁽⁴⁵⁾. A classic myth is that resistance training will stunt the growth of youths. This myth, together with other misconceptions, such as the fact that resistance training will lead to youths becoming musclebound and slower, has made the lay public believe that children and adolescents should not participate in resistance training. However, no scientific evidence exists to support these misconceptions ^(24;49). To the contrary, several medical associations and societies have published position and policy statement papers advocating the practice of resistance training among children and adolescents. These associations and societies include the American Academy of Paediatrics (AAP) ⁽⁴⁹⁾, the US National Strength and Conditioning Association (NSCA) ⁽²⁴⁾, the Canadian Society for Exercise Physiology ⁽⁵⁾, the British Association of Sports and Exercise Science (BASES) ⁽⁶⁹⁾, the Australian Strength and Conditioning Association (ASCA) ⁽⁴⁾, and the American Orthopaedic Society for Sports Medicine (AOSSM) ⁽³⁾. These policy and position statements, together with several review articles ^(7;22;27;31;40;48) agree that resistance training, when performed using proper technique and strict supervision, is a safe, effective and recommended training modality for children and adolescents.

The purpose of this manuscript is therefore to review the current literature on resistance training among youths, and to formulate evidence-based guidelines for safe and effective resistance training.

HISTORICAL OVERVIEW AND DISPELLING THE MYTHS:

Original concerns about youth participating in resistance training arose from the data gathered by the National Electronic Injury Surveillance System (NEISS) of the United States Consumer Product Safety Commission. The NEISS data reported in 1979 that more than half of the 35,512 resistance training-related injuries requiring emergency-room treatment involved youths ranging from 10 to 19 years of age ⁽⁷⁴⁾. In 1987, the commission published further data showing that 8,590 children aged 0 - 14 years old visited the emergency room due to weightlifting-related injuries ⁽⁷⁵⁾.

In addition to the injury fears highlighted by the NEISS data, various case reports also detailed epiphyseal (growth plate) fractures among youths during resistance training. In one of the earliest reports of such injuries among youths, Ryan and Saliccolli ⁽⁶⁰⁾ reported fractures of the distal radius epiphysis (growth plate) in five adolescent boys aged 14 - 17. All five adolescent boys fractured their wrists while performing the military press; however, the specific risk factors and mechanisms of injury were not reported ⁽⁶⁰⁾. A further case series by Gumps et al. ⁽³⁹⁾ reported two cases of bilateral radius and ulna epiphysis and/or metaphysic fractures, and described the inciting events. These studies, among others ^(6;10;11;43;79), raised concern among physicians and are more than likely the source of the misconception that resistance training among youths may lead to growth plate damage and premature closure of the epiphysis, thereby stunting growth.

Although the initial NEISS incidence data, as well as the few reports on radial epiphysis fractures during weightlifting in adolescents seems alarming, they do not provide any information on the predisposing factors that led to the injuries. The overwhelming majority of these injuries may be attributed to improper technique, excessive loading, and/or other accidents resulting from improper weightlifting practice ^(39;60) – all of which may have been avoided with adequate supervision.

As a result of the growing concern regarding injury and potential detrimental consequences to children and youth participating in resistance training, the AAP published their first position statement in 1983 to clarify and review the evidence ⁽¹⁾. They concluded that “teenagers who wish to participate should take proper safety precautions and have capable supervision”. In addition, it was also stated that “minimal benefits are obtained from weight training in the pre-pubertal athlete” ⁽¹⁾. It was speculated that pre-pubertal boys do not significantly improve strength or muscle mass during weight training due to insufficient circulating androgens ⁽¹⁾. This speculation was based on a single study among pre-adolescents that reported no significant change in the strength of the limbs after weight training ⁽⁷⁸⁾. The initial studies investigating the efficacy of pre-adolescent strength training programmes can be criticised on the basis of study design limitations, and their largely negative results should not

be taken as support for the ineffectiveness of resistance training during pre-adolescence ⁽⁷⁾. More recent studies provide strong evidence that resistance training, given sufficient intensity, volume and duration, results in a substantial increases in strength among pre-adolescents (Reviewed in ⁽⁷⁾). Due to the increased body of evidence suggesting that pre-adolescent strength training may result in strength increases without significant injury risk, the AAP changed their recommendation for children in their 1990 position statement ⁽²⁾. In this statement they recommend that strength training programmes should be permitted for pre-pubescent, pubescent, and post-pubescent athletes, but only if conducted by well-trained adults ⁽²⁾. However, this statement still strongly raised the concerns about risk of injury. A further recommendation stated: *"Unless good data demonstrates safety, children and adolescents should avoid the weight lifting, power lifting and bodybuilding, as well as the repetitive use of maximal amounts of weight in strength training programmes until they have reached tanner stage 5 level of developmental maturity (age 18-20)"*.

Furthermore, a 1964 Japanese study raised concern about the growth-arresting potential of lifting heavy loads during childhood ⁽⁴⁴⁾. This study reported that Japanese children who were exposed to heavy lifting and heavy loads during manual labour had a reduced stature ⁽⁴⁴⁾. However, since this original report nine studies ^(20;21;55;56;61;62;68;78;80) in children and adolescents reported mean height differences before and after resistance training programmes. These studies indicate that the resistance training protocols do not negatively affect growth. Most notably, the 21-month-long resistance training study by Sadres et al. ⁽⁶¹⁾ in thirty (30) 9 to 10-year-old boys reported mean gains in linear height of 9.7 cm. These studies suggest that well-prescribed, supervised resistance training studies have no detrimental effect on stature. In contrast to original lay public perceptions, medical bodies are now making statements such as: *"...quality resistance exercise programmes support natural growth and maturation..."* ⁽⁶⁹⁾

Since the original concerns regarding youth participating in resistance training arose, several research studies investigated various modes of resistance training and resistance training programmes within youth and adolescents. These have provided the required evidence that resistance training is both safe and effective when proper techniques and safety precautions are followed (see Injury Risk section) ⁽²⁷⁾. Today, the outdated concerns about resistance training have been overcome with scientific evidence that resistance training may be safe and effective, as well as offer considerable health and fitness value to children and adolescents. This opinion is shared by numerous medical bodies, including the AAP ⁽⁴⁹⁾, NSCA ⁽²⁴⁾, the Canadian Society for Exercise Physiology ⁽⁵⁾, BASES ⁽⁶⁹⁾, ASCA ⁽⁴⁾ and AOSSM ⁽³⁾.

INJURY RISK:

As previously discussed, clinicians once considered resistance training unsafe and potentially injurious to the developing musculoskeletal system^(1,2). Over the past two decades, evidence related to the relative safety of resistance training among children and adolescents has increased. Numerous studies have investigated a wide variety of resistance training programmes among children and adolescents (Table 1). In a total of 26 prospective studies (19 in children and 7 in adolescents) that investigated resistance training programmes in a total number of 762 youths (502 children and 260 adolescents), only 3 injuries were reported, namely: anterior shoulder pain (resolved within 1 week)⁽⁵⁷⁾, a shoulder muscle strain (resulted in only 1 missed training session)⁽⁴⁶⁾, and an anterior thigh pain (pain resolved after 5 minutes)⁽⁶¹⁾. These three studies reported estimated injury rates of 0.176⁽⁵⁷⁾, 0.053⁽⁴⁶⁾ and 0.055⁽⁶¹⁾ injuries per 100 participants, respectively. Furthermore, Rians et al.⁽⁵⁷⁾ found no evidence of musculoskeletal injury (measured by biphase scintigraphy) or muscle necrosis (determined by creatine phosphokinase levels) among children in their 14-week period of progressive resistance training.

Although injuries do occur during supervised resistance training programmes, the injury rates remain much lower than several other activities, indicating that resistance training is markedly safer than several other sports. In one study⁽⁴¹⁾, the injury rates of resistance training, weightlifting and rugby were compared in adolescents. The overall number of injuries per 100 participant hours (injury rate) was lower in resistance training (0.0120 injuries per 100 participant hours) and weightlifting (0.0013 per 100 participant hours), when compared to rugby (0.8000 injuries per 100 participant hours)⁽⁴¹⁾.

Today, the NEISS continues to publish the prevalence, severity and mechanism of injury for all acute injuries on their online database (www.cpsc.gov/library/neiss.html). This excellent resource allows any person to view all injuries that presented to hospital emergency rooms, as well as the reason for injury and the diagnosis. As an example, during 2009, the participating emergency rooms recorded 598 injuries that occurred as a result of weight lifting (Weight lifting code in online database; 3265) to youths (age 6 to 17 years old). This sample count equates to a National (United States) injury estimate of 19 675. To place this estimate into a South African context, the population of the USA is approximately six times larger (USA 307-million; SA 49-million) than the population of South Africa.

Before one is alarmed by these figures, it is important to peruse the narrative provided for each injury. An overwhelming majority of injuries occur as a result of accidents and events not related to the practice of resistance training. As an example; "PT DROPPED A 10 LB. WEIGHT ON FOOT @ HOME. C/O SWOLLEN FOOT AND PAIN. DX: FOOT FRACTURE" and "PT PLAYING WITH A 10 LB DUMBBELL WHEN SHE GOT HER FINGER CRUSHED SUSTAINED A HEMATOMA TO FINGER". Moreover, Meyer et al.⁽⁵¹⁾ noted that two thirds of injuries sustained by 8 to 13-year-olds occurred as a result of injury

mechanism descriptions including the words “dropping” or “pinching”. These data clearly illustrates the importance of strict supervision by competent strength and conditioning coaches.

Without appropriate supervision, accidents leading to a catastrophic event may occur during resistance training. In one case report ⁽³⁷⁾, a nine-year-old boy died after a barbell rolled off the supports of a bench press and fell on his chest. Similar accidents have also been reported in men ⁽⁴⁷⁾. Therefore, the greatest risk to children and adolescents in the gymnasium (weight room) is not the improper use of resistance training equipment, but rather their irresponsible misuse as well as accidents which may occur in the weight room.

Table 1: Resistance Training Intervention Studies in Children and Adolescents

Reference	Participants	Type of Exercise(s)	Duration	Injuries
STUDIES IN CHILDREN				
Vrijens et al., 1978 ⁽⁷⁸⁾	28	“Isotonic” exercises	8 weeks	0
Sewall and Micheli, 1986 ⁽⁶⁵⁾	10	Weight machine	9 weeks	0
Funato et al., 1987 ⁽³⁶⁾	52	Maximum Isometric Elbow Flexion	12 weeks	0
Rians et al., 1987 ⁽⁵⁷⁾	18	Hydraulic Machine Circuit	14 weeks	1
Siegel et al., 1989 ⁽⁶⁸⁾	50	Free weight, tubing and bodyweight	12 weeks	0
Ramsay et al., 1990 ⁽⁵⁶⁾	13	Free weights and weight machines	20 weeks	0
Faigenbaum et al., 1993 ⁽²¹⁾	14	Weight Machines	8 weeks	0
Ozmun et al., 1994 ⁽⁵²⁾	8	Dumbbell Elbow Flexion	8 weeks	0
Faigenbaum et al, 1996 ⁽²⁰⁾	15	Weight Machines	8 weeks	0
Falk and Mor, 1996 ⁽³⁰⁾	14	Body Weight	8 weeks	0
Lillegard et al., 1997 ⁽⁴⁶⁾	52	Free Weights and Machines	12 weeks	1
Hetzler et al., 1997 ⁽⁴²⁾	20	Free Weights and Machines	12 weeks	0
Faigenbaum et al., 1999 ⁽²⁹⁾	31	Weight Machines	8 weeks	0
Sadres et al., 2001 ⁽⁶¹⁾	27	Free Weights	21 months	1
Pikosky et al., 2002 ⁽⁵⁵⁾	7	Weight Machines and Body Weight	6 weeks	0
Flanagan et al., 2002 ⁽³³⁾	38	Weight Machines and Bodyweight	10 weeks	0
Faigenbaum et al., 2002 ⁽²⁶⁾	55	Weight Machines	8 weeks	0
Tsolakis et al., 2004 ⁽⁷³⁾	9	Weight Machines	8 weeks	0
Faigenbaum et al., 2005 ⁽¹⁹⁾	41	Weight Machines	8 weeks	0
Total (19 studies)	502		200 weeks	3
STUDIES IN ADOLESCENTS				
Coutts et al., 2004 ⁽¹³⁾	21	Free Weights	12 weeks	0
Gonzalez-Baldillo et al., 2005 ⁽³⁸⁾	51	Free Weights	10 weeks	0
Faigenbaum and Mediate, 2006 ⁽¹⁸⁾	69	Medicine Ball Training	6 weeks	0
Faigenbaum et al., 2007 ⁽¹⁶⁾	27	Free Weights and Body Weight	6 weeks	0
Faigenbaum et al., 2007 ⁽²⁵⁾	22	Free Weights	8 weeks	0
Szymanski et al., 2007 ⁽⁷⁰⁾	49	Free Weights and Medicine Ball	12 weeks	0
Channell et al., 2008 ⁽¹²⁾	21	Free Weights and Body Weight	8 weeks	0
Total (7 studies)	260		62 Weeks	0

Table adapted from Faigenbaum and Meyer, ⁽²⁷⁾.

PHYSIOLOGY

Muscle adaptations, from muscle hypertrophy and changes in fibre type composition to properly-designed resistance training programmes, are well established in adults. These morphological changes are however not as well characterised among children and adolescents⁽⁵⁾. Studies using anthropometric techniques to determine changes in muscle mass from resistance training have provided no evidence of increased muscle hypertrophy in children after resistance training interventions^(17;52;62;68), and very little evidence in adolescents⁽⁴⁶⁾. However, when more accurate measurement techniques (magnetic resonance imaging [MRI] and ultrasound) were used to assess the efficacy of resistance training among children, two studies found small increases in muscle mass^(50;59). In the first study, Mersch and Stoboy⁽⁵⁰⁾ demonstrated an increase in quadriceps cross-sectional areas (CSA), measured by MRI. Thereafter, Fukunaga et al.⁽³⁵⁾ found a significantly increased muscle and bone CSA in children after performing 12 weeks of elbow extensions. These studies do however have several limitations and further research is required to establish whether whole-muscle hypertrophy does occur in children. The findings showing no evidence^(52;56;62;68) of muscle hypertrophy from resistance training in children have been attributed to the inadequate levels of testosterone to stimulate an increase in muscle mass. Among adolescents, moderate gains in body segment girths and decreases in skinfold girths have been reported after a 12-week progressive resistance training programme⁽⁴⁶⁾. The relatively small effect, if any, of resistance training on muscle hypertrophy in children and adolescents remains challenging to detect due to the natural occurring rate of growth during the developmental years⁽⁵⁹⁾.

Despite youths showing no difference or very modest changes in muscle size during progressive resistance training programmes, both children and adolescents have shown significant increases in muscle strength, beyond the strength changes which occur during normal healthy growth and maturation^(8;14;18-20;20;21;21;25;26;29;30;32;46;54-56;62;65;68;68;70;73;77;80-82). The mechanisms of increased strength gain is therefore largely independent of muscle size. Two meta-analyses on the effectiveness of youth resistance training on strength adaptation have been performed^(32;53). Falk and Tennebaum⁽³²⁾ calculated an effect size of 0.57 for children (<12 years for boys), whereas Payne et al.⁽⁵³⁾ revealed effect sizes between 0.65 and 0.83 for youths aged 6 to 18. These values indicate that the effect of resistance training on strength improvements in youth is large. Strength gains of approximately 30% are typically reported following short-term (8-20 weeks) resistance training programmes^(8;14;18-20;20;21;21;25;26;29;30;32;46;54-56;62;65;68;68;70;73;77;80-82). Moreover, strength gains of up to 74% have been reported in a study after only 8 weeks of progressive resistance training using weight machines⁽²¹⁾.

Since there is minimal evidence of increased muscle size, neurological adaptation has been proposed as the primary mechanism of strength gain in youths^(5;24). Neurological adaptation refers to modifications in coordination and learning that facilitate better recruitment and activation of muscle^(34;63). Only two studies have shown direct evidence of neurological changes following resistance training^(52;56).

The changes in neuromuscular activation reported in these studies did however not account for the changes in muscle strength. Although not directly measured, it has been proposed that improved inter-muscular coordination and muscle learning may account for the strength increases not accounted for by the increased neuromuscular activation ^(5;24). In support of this hypothesis, Faigenbaum et al. ⁽²⁹⁾ demonstrated that high-repetition, low-load training, compared to low-repetition, high-load training results in similar enhancement of maximal strength. In adults, a low-repetition high-load programme is required for maximal strength gains, but it seems as if children without previous experience will benefit from any mode of resistance training.

GUIDELINES FOR STRENGTH TRAINING

As a pre-requisite, all children and adolescents performing resistance training should receive instruction and be closely supervised by a qualified strength and conditioning professional ^(3;5;7;22;24;27;31;40;48;49;69). In addition, it should be appreciated that children and adolescents have special physical and psychosocial uniqueness. Youth resistance training programmes should therefore be carefully prescribed and progressed according to an individual's physical maturation, training experience, and stress tolerance. The needs, goals and interests of the children and adolescents should always be put first; they should only willingly participate and should never be forced or pressured into participation.

Although there is no evidence that there should be a minimal age requirement, only children who are physiologically and psychologically ready should participate ^(3;5;5;24;69). However, assuming children are already playing rugby, it may be generally assumed that they are ready for some form of resistance training. A pre-participation medical exam is not necessary for apparently healthy youths; however, a medical examination is recommended for youths with known and/or suspected health problem(s) (e.g. orthopaedic disorders, diabetes, obesity) ^(5;24).

To further ensure the safety of resistance training programmes, always ensure that the exercise environment (weights room or gymnasium) is free of any possible hazard. Basic education on correct training technique, training guidelines, exercise-room etiquette, spotting techniques and the use of collars should be part of resistance-training programmes. Youths should be encouraged to embrace self-improvement; however, the emphasis should not be to lift heavy weights, but rather to correctly perform the more difficult multi-joint exercises.

When designing a resistance training programme, the following variables need to be considered: (i) warm-up and cool down, (ii) choice and order of exercises, (iii) training intensity and volume, (iv) rest intervals between sets and exercises, (v) repetition velocity, (vi) training frequency, and programme variation ⁽²⁴⁾.

Recent research has led to new thoughts regarding warm-ups. Static stretches are no longer believed to be the most suitable method of preparation for physical activity ^(66;71). An acute bout of static stretching has been shown to reduce the power performance among adolescents ^(64;83). Research supports the opinion that dynamic movements (e.g. hopping, skips, jumps, and movement-based exercises for the upper-body) should be performed during the warm-up period ^(23;58). Such a dynamic warm-up period may enhance power performance in youth ^(15;23;67;72). It is suggested that dynamic movements are performed for 5-10 minutes before training. Static stretching is still recommended during the cool-down period after training sessions ⁽⁶⁶⁾. The cool-down period should also be used to emphasise the principles taught during the session.

Various different types of resistance exercises (weight machines, free weights, elastic bands, medicine balls, bodyweight exercises, etc.), as well as programmes varying from single-set to multi-set exercises may be performed. However, appropriate resistance exercises, as well as resistance training programmes, should be prescribed according to the player's body size, training history and exercise technique experience ^(5;24). It is recommended that youth starting resistance training should follow resistance training programmes on 2 or 3 non-consecutive days each week. Furthermore, they should include 8 to 12 exercises that strengthen the whole body. Initially 1 or 2 sets of 8 to 15 repetitions should be performed with a light to moderate load to enable youths to learn proper technique ^(5;24). Generally, a weight approximately 30-60% of the player's 1-repetition maximum (RM) should be selected ^(5;24). Programmes should be designed in such a way that large muscle group exercises and multi-joint lifts are performed before smaller muscle group exercises and single joint exercises, respectively ^(5;24). For the more experienced player performing challenging exercises such as weightlifting movements (Olympic lifts) and plyometrics, these exercises should be performed early in the training session before the players are fatigued ^(5;24).

For youth players with resistance training experience, the programmes may be progressed to meet specific training objectives. For example, performing 3 sets with a heavier load that allows between 6 to 10 repetitions before volitional fatigue (6 to 10 RM), may increase strength on large muscle group exercises. Progression may also be achieved by performing selected exercises to enhance movement speed, and therefore power generation. Examples of such exercises are Olympic lifts and plyometric drills. Various exercises to reduce the risk of injuries have been proposed ⁽⁷⁶⁾. Balance and coordination exercises have been recommended to be incorporated into youth resistance training programmes, as balance is important for optimal performance and prevention of injuries ⁽⁷⁶⁾. In addition, abdominal, hip and lower-back exercises aimed at strengthening the trunk should also be included to reduce the risk of injury ⁽⁵⁾.

The velocity at which exercises are performed may affect the adaptations to resistance training exercises. It is generally recommended that youths perform exercises in a controlled manner at moderate velocity ^(5;24). However, different training velocities may be used for certain exercises. Olympic-style lifts and plyometric drills performed by more experienced youths should be performed at high velocities ^(5;24). While children and adolescents are performing sets of moderate intensity, it is recommended that they rest for about 1 minute between sets ^(5;24). Although longer rest is normally recommended for adults, youth have been shown to be able to resist fatigue to a greater extent than adults during several repeated sets of resistance exercises ⁽²⁸⁾.

To keep the training programme challenging and effective, systematic variation in exercise intensity and volume should be incorporated. Programme variation, including adequate recovery between training sessions, will allow youths to further enhance resistance training programmes ^(9,45). In some cases, variation as simple as less-intense training sessions may provide youth and adolescents the required variation during long-term sports resistance training programmes.

Table 2: A summary of the general youth resistance training guidelines

<input type="checkbox"/> All children and adolescents require qualified instruction and close supervision by a qualified strength and conditioning professional to ensure safe and effective resistance training.
<input type="checkbox"/> There is no minimum age; rather, young children should be physiologically and psychologically ready to participate in a resistance training programme.
<input type="checkbox"/> The exercise environment (weights room or gymnasium) should be safe and free of hazards.
<input type="checkbox"/> The qualified strength and conditioning professional should educate players on correct training technique, training guidelines, exercise-room etiquette and spotting technique.
<input type="checkbox"/> Each session should begin with a 5 to 10 minute dynamic warm-up period.
<input type="checkbox"/> Start resistance training on 2 or 3 non-consecutive days each week.
<input type="checkbox"/> Begin with 8-12 exercises that strengthen the whole body (upper body, lower body and midsection).
<input type="checkbox"/> Initially perform 1 or 2 sets of 8 to 15 repetitions (approximately 60% 1RM) with a light to moderate load to learn proper technique.
<input type="checkbox"/> The focus should be on learning the correct exercise technique and safe training procedures instead of the amount of weight lifted.
<input type="checkbox"/> Balance and coordination exercises, as well as abdominal, hip and lower-back exercises should be included to reduce injuries.
<input type="checkbox"/> Gradually progress to more advanced movements that enhance power production.
<input type="checkbox"/> Cool down with static stretching; this period should also be used for the qualified strength and conditioning professional to emphasise the principles taught during the session.
<input type="checkbox"/> Vary the training programme over time to optimise adaptation and reduce boredom.

CONCLUSION

Concerns regarding youth participating in resistance training have no scientific basis. Children and adolescents are able to significantly improve power performance through resistance training. However, to ensure safety, all children and adolescents should be closely supervised and should follow programmes carefully considered by strength and conditioning professionals.

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