Coach awareness, knowledge and practice in relation to growth and maturation and training load in competitive, young gymnasts

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Abstract
Growth-related and overuse injuries are commonly reported in young gymnasts. Two risk factors of these injuries are growth and maturation, and training load. However, little is known regarding current coaching knowledge and practice in relation to these risk factors. To help understand current knowledge and practice, 44 coaches of competitive, young gymnasts, from 3 gymnastics disciplines (men’s artistic, women’s artistic, trampoline) took part in focus groups. The focus groups explored the awareness, experience and practice of coaches in relation to growth and maturation, training load and injury in competitive, young gymnasts. Data were analysed manually using an inductive thematic approach to identify core themes. The findings showed that coaches were aware of the physical changes and injuries that occur during the adolescent growth spurt. Both psychological changes and skill loss/confusion were also identified as challenges during this time. The knowledge and practice of monitoring growth and maturation, and training load did however differ between disciplines. Sports science and medicine practitioners were recognised as key stakeholders in helping manage and reduce the risk of injuries during growth. There appears to be gap between coach knowledge of growth and maturation, and training load, and practices such as monitoring training load and growth. Educating coaches and further research in these areas will aid coaches in reducing the risk of injuries in young, competitive gymnasts.

Keywords
Artistic gymnastics, injury, trampolining, youth sport

Introduction
A number of ‘Academies’ and ‘Performance Pathway’ systems now exist in both professional and Olympic sport. Through expert coaching and resources, these systems intend to develop talented youth athletes into senior elite athletes. There are, however, concerns over the injury risk associated with youth athletes.¹,² Growth and maturation and training load have been recognised as two risk factors of injury in youth athletes. The adolescent growth spurt has been identified as a time when youth athletes are at an increased risk of injury.³–⁵ During the adolescent growth spurt, the growth plates become more fragile and less resistant to forces.⁶–⁸ Additionally, the development of muscle and bone occurs asynchronously leading to an imbalance between growth and strength.⁹ Coupled with repetitive loading through training, these changes during the adolescent growth spurt may increase the risk of injury. It has also been suggested that the development of sensorimotor mechanisms combined with
rapid growth may contribute to changes in motor performance and therefore increase injury risk. However, the research associating the development of sensorimotor mechanisms during the adolescent growth spurt and injury risk is currently limited. Similarly, high training loads and sudden increases in training loads have been linked to an increased risk of injuries in youth athletes. Such risks are of particular concern in gymnastics, where the volume of training is evidently high, and a number of acute and overuse injuries have been reported. The most common injuries reported in young gymnasts include but are not limited to ankle sprains, gymnast’s wrist, Osgood-Schlatter’s disease and spondylosis.

However, little is known regarding coaches’ current knowledge and understanding of the adolescent growth spurt and training load, and whether these risk factors for injury influence coaching practice in gymnastics. Understanding current knowledge and practice in relation to growth and maturation, and training load will help identify areas required to further develop and support coaching practices. With this in mind, the aim of the investigation was to understand current coach awareness, knowledge and practice in relation to growth and maturation, and training load in competitive, young gymnasts. This study will establish areas for future research and education required by coaches to aid coaching practices in competitive, young gymnasts.

Materials and methods

Study design

A qualitative research design using an interpretivism approach by means of focus groups was chosen for this study to gain a ‘richer’ understanding of the current knowledge and practice of coaches in relation to the topic areas. The Consolidated Criteria for Reporting Qualitative Research was used to demonstrate credibility of the study (Appendix 1).

Research team

The focus groups were conducted by a single moderator (T.S.Patel, MSc, CSCS, ASCC, PhD Candidate, Female) with no personal experience in gymnastics. Prior to data collection, the moderator had been embedded into the National Governing Body for approximately six months. The moderator had received focus group training (Conducting Focus Groups, Social Research Association) and completed a pilot focus group prior to the study. No relationships were established between the moderator and coaches with the exception of the National coaches (n = 6) who were already acquainted with the moderator. All other coaches were only aware of the PhD candidate role held by the moderator at the National Governing Body. The wider research team were aware that the participants’ knowledge of the moderator’s role within the National Governing Body may influence the findings in this study.

Participants

A purposive sample of coaches; who at the time were directly involved with competitive, young gymnasts (age 9–16) on the British Gymnastics pathway programme (Foundation, Development, Junior or equivalent) for men’s artistic gymnastics (MAG), women’s artistic gymnastics (WAG) and trampoline gymnastics (TRA), were selected to take part. A total of 70 eligible coaches were invited to take part via email invitation from the Head National Coach of each discipline. Two coaches openly declined to participate due to time constraints. Forty-four (28 Male; 16 Female) coaches (11 MAG, 15 WAG, 18 TRA), from different clubs across the country, with varying degrees of employment status (6 National Coaches, 4 Sub-contracted National Coaches, 3 Home Nation Coaches, 31 Club Coaches) and experience took part in the study. All coaches had a minimum of a level 2 coaching qualification in gymnastics. Coaches were provided with a participant information sheet and completed a written consent form to participate in the study, approved by the University of Bath Research Ethics Approval Committee for Health.

Focus groups

Coaches participated in a single, discipline specific focus group session. Eight focus groups were conducted in total (2 MAG, 3 WAG, 3 TRA) each with a minimum of 4 coaches and a maximum of 7 coaches. Only the moderator and coaches were present during the focus groups. All focus groups took place at the National Performance Centre (Lilleshall National Sports Centre, UK) between the middle of October 2018 and the end of January 2019. Focus groups were organised in accordance to each coach’s position within British Gymnastics’ pathway programme to encourage honesty and openness amongst all coaches. Focus groups were recorded on two audio recorders (H1n, Zoom, UK).

Consistent with the approach of Cumming and colleagues, both written and verbal methods were used in the focus groups. At the beginning of each focus group, each coach was provided with a pen and pad of sticky notes and instructed to write on separate sticky notes “3 things which come to mind when thinking about growth and maturation in gymnasts”.
Coaches were next instructed to work as a group to cluster their thoughts into themes. The total duration of the task was ~5min. The moderator then asked the groups to explain each theme.

Conversation from the group activity led into the main interview section of the focus group. The main interview section was semi-structured in design and constructed from both the literature and observations of the moderator. The topic guide covered the awareness, experience and practice of coaches in relation to growth and maturation, training load and injury in competitive gymnasts (Appendix 2), which had been piloted with physiotherapists working in gymnastics prior to data collection. The semi-structured design allowed for flexibility of the questioning schedule and opportunity to explore additional topics not included in the original questioning schedule.

Analysis

Focus groups ranged between 65 and 114 min in length (mean = 81 min). No additional field notes were made during or immediately following focus groups. The data from the focus groups were professionally transcribed verbatim using an external company (TypeItWrite UK Ltd, UK) for analysis purposes. Any identifiable names were anonymised and replaced with pseudonyms. Transcripts were not returned to coaches to minimise any additional burden.

Transcribed focus groups were analysed manually by the moderator in Microsoft Excel (Microsoft Excel for Mac, Version 16.21, Microsoft 2018). An inductive thematic analysis approach was used to analyse focus groups using the procedure described by Braun and Clarke. The data was then collated into disciplines (MAG, WAG, TRA) to better understand the current awareness, knowledge and practice from each discipline.

Reflexivity

Discipline-specific interpreted findings were presented to all available coaches (participants and non-participants) through workshops during camps. During the workshops, coaches were given the opportunity to clarify and further discuss the findings for their discipline. This process was used as a form of synthesised member checking to enhance trustworthiness of the interpreted data.

Results

Seven core themes and seven sub-themes were identified through inductive thematic analysis using the focus group topics as an initial guidance. Definitions of core themes and a list of sub-themes are presented in Table 1. Overall, the majority of findings were similar across the three gymnastics disciplines. Further supporting quotes are presented in Appendix 3.

Physical changes during growth & maturation

Coaches identified a number of physical changes that occurred in gymnasts during puberty. These changes included rapid growth in stature and mass, a change in centre of mass position, and changes in body composition. Coaches also described functional capacity changes where strength, power-to-weight ratio and flexibility all changed.

Table 1. List of core themes, associated sub-theme(s) and core theme definitions.

| Theme | Definition |
|-------|------------|
| 1. Physical changes during growth and maturation | Physical changes during growth and maturation that have been identified by coaches. |
| 2. Temporary skill loss/confusion in youth gymnasts | Temporary changes in gymnastic skills as a result of growth and maturation. |
| 3. Psychological challenges in pubertal gymnasts | Challenges faced by coaches in regard to psychological changes in youth gymnasts during growth and maturation. |
| 4. Injuries in youth gymnasts | Injuries and prevention of injuries in youth gymnasts |
| SUB-THEMES: Injury causes, Injury Types, Injury Prevention during Growth | |
| 5. Training load in youth gymnasts | Training and monitoring practices in youth gymnasts |
| SUB-THEMES: Planned training, Adapting training, Monitoring training | |
| 6. Monitoring growth and maturity in gymnasts | Methods used to monitor growth and maturity in gymnasts |
| SUB-THEME: Weight monitoring | The knowledge and support from sports science and medicine practitioners identified by coaches around growth and maturation, training load and injury |
| 7. Gymnastics specific medical and scientific knowledge and support | |
"We’ve got big changes, physical changes, change of centre of mass, growth spurt, body weight so all the physcials together and the range really with those is there are large changes, growth spurs, quick changes and some gains, physical mass, which obviously affects the biomechanics of what they’re doing, as well as it being a positive thing and gaining strength." (MAG Coach 1)

These changes were predominantly seen to have more impact on the performance of female gymnasts.

"Because I tend to find, personally, that females sometimes have more ... it tends to impact them a bit more. When they are going through puberty, and I see, like, for example, more of a shift in the alignment in their hips and so on ... " ... Because I tend to find foot alignment a lot worse in females than males ..." (TRA Coach 15)

Temporary skill loss/confusion in youth gymnasts

One of the main challenges identified by coaches in all disciplines was the temporary loss/confusion of gymnastics skills associated with periods of rapid growth. Coaches explained that gymnasts were unable to perform some of the skills that they were previously able to do as a result of their bodies changing. Changes in timing of the skill, coordination, body awareness, centre of mass and rotation were all factors that coaches associated with temporary skill loss/confusion.

"Levers get longer. Kids can talk about losing skills. They need to learn the new perception of the limb lengths." (MAG Coach 6)

"... But [pause] they are suddenly having a hard time holding a shape, for example. If they grow in height, then it’s very hard to hold a shape that they are used to conditioning at a certain height, even if it’s one or two centimetres, especially with the bars. Even if it’s ... from a handstand, the full down, holding their shape in a dish shape, they suddenly are sticking their bum out and they don’t understand why can’t hold a plank hold. But that’s to do with their changing body." (WAG Coach 12)

Coaches from all disciplines emphasised the need to help gymnasts understand the reasons why they are experiencing skill loss/confusion.

"When it’s been a frustration thing, I think just positive re-enforcement and making sure they understand why it’s happening, so going back to making sure that they know it’s because they’re growing. Just having that conversation that things might feel different, but it doesn’t necessarily mean that you can’t do the skill, or you might see something slightly different or you might land slightly different, it doesn’t mean that the skill has totally changed. It’s just a slightly different feeling. So, maintaining them strong, keeping them strong mentally more than anything through it." (TRA Coach 1)

Psychological challenges in pubertal gymnasts

Coaches from all disciplines expressed the psychological related challenges they had experienced with pubescent gymnasts. Coaches described gymnasts as experiencing more emotions such as crying, frustration, bad moods and a decrease in confidence. An increase in these emotions were attributed to gymnast’s hormones, injuries, loss of skills and gymnasts not understanding the changes happening with their body. During this time, coaches also described their gymnasts often displayed a lack of motivation and focus. Some coaches found their gymnasts were not compliant with instructions during this period of time. Two coaches linked these changes in behaviour, attitude and moods to dropout.

"So, I’ve had Sammie for example, really good, progressing really well, had a quite quick rapid growth. She grew, I can’t remember how much but it was quite a lot in a short amount of time. In the weeks following that or during that stage, her motivation, to me it looked like she didn’t want to be there. To her, I don’t think it was that, she was getting frustrated with everything. She couldn’t do what she used to be able to do because of her body shape changes and the amount of hours she was doing, just because we were having to repeat or go back, made her feel negative ..." (TRA Coach 2)

Injury in youth gymnasts

Sub theme: Injury causes. In all disciplines, rapid growth was perceived as one of the main causes of injury in young gymnasts.

"Because, obviously, if they are going through their growth spurt, that’s when they are more prone to injury due to their bones and stuff like that." (TRA Coach 11)

"Yeah, it’s just basically they’re growing more frequent injuries because landings and stuff, the muscle’s growing away from the bone ..." (MAG Coach 10)

Artistic coaches (MAG and WAG) also associated injuries with an increase in the number of skills or routines, an increase in the difficulty of skills and
skill loss. Additionally, twisting and landing elements of skills were suggested as causes of injuries.

‘I think it’s from twisting combinations on the floor. That’s where I think mine came from, taking off like this.’ (MAG Coach 8)

A few TRA and WAG coaches linked injuries to not being physically prepared and additional body weight. Other causes of injuries highlighted by individual coaches included high training loads during periods of rapid growth, overload and spikes in training, repetition of similar movement patterns, lack of concentration and communication from gymnasts, and coaches pushing too hard.

Sub theme: Injury types. Growth related injuries including Osgood-Schlatter’s disease and Sever’s disease were commonly named by coaches in all three disciplines. Osteochondritis dissecans of the elbow was frequently mentioned as a common injury by artistic coaches. Coaches from all disciplines reported stress fractures of the back in their gymnasts. Additionally, MAG coaches identified stress fractures of the wrist.

‘It’s just like the period of time where you’re at risk of overloading the body and you get stress fractures and stuff, especially shin splints and the stress factors in your back, Osgood-Schlatter disease and ankle and knee, hip, joint problems.’ (TRA Coach 3)

Each discipline also identified injuries specific to their sport. Shoulder injuries were frequently mentioned in MAG gymnasts, whilst TRA coaches reported hip, knee, shin and ankle problems in their gymnasts. Many WAG coaches also reported hamstring injuries.

Sub theme: Injury prevention. Coaches from all disciplines described methods used to prevent injury. MAG coaches spoke about a proactive approach towards injury i.e. using prehabilitation exercises or reducing training load. A few MAG coaches suggested this could be applicable to those gymnasts experiencing growth. Individual MAG coaches also prevented injury by lowering repetitions of more difficult skills, avoiding too much impact and using pain as an early indicator of injury.

‘You know, you can— if you’re doing like 1,000 circles in a session on Pommel, you might say, let’s just do 500 and save your wrists a little bit. I think it can be used as proactive.’ (MAG Coach 6)

Many of the TRA coaches reduced training volume during the growth spurt in order to prevent injury. A few WAG coaches described solutions for preventing injury during rapid growth including prehabilitation during the growth spurt, reducing load before rapid growth, communicating with gymnasts and training harder skills in safer scenarios.

‘Yes, injuries. I guess when they’re growing, they’re more susceptible to injuries. I guess it’s our job to try and reduce that risk and like Missy said, try and pre-empt it and take the load off before so they can go through it as easily as possible.’ (WAG Coach 7)

Training load in youth gymnasts

Sub theme: Programmed training. In all disciplines, training comprised of apparatus work, and physical preparation, which includes, strength work, conditioning, prehabilitation and flexibility. Artistic gymnastics training also involved aspects of ballet and or choreography. Artistic coaches emphasised that a high volume of training was necessary to meet the performance requirements of the sport. The volume of training reported by coaches varied for gymnasts at similar levels in all disciplines, but particularly in the artistic disciplines. For example, MAG gymnasts on the Development programme were reported to be training between 18 and 30 hours a week.

(A) ‘My boys do between 30 and 32, 33 hours a week.’

(B) ‘I’m about 10– I’m about 10 hours less than that. So it’s 22 hours for my elite kids. The boys that are in the elite performance squad do 20, 22 hours.’ (MAG Coaches 8 & 9)

The majority of coaches from all disciplines planned training towards competitions, where some coaches planned training more in advance than others. Many of the coaches described that the intensity of training would increase towards a competition and then taper off just before a competition. This was typically done by increasing the number of routines performed in a session and then reducing the number of routines performed just before competition.

‘Well, obviously, say two months before competitions, you normally start to introduce routines or half routines. And then it builds up the numbers. And then obviously you start to water it down number-wise. So, the week before you might only ask for one or two routines, where-as two- or three-weeks prior would have been five, six depending on’ (WAG Coach 1)

Sub theme: Adapting training. Training was adapted by many TRA and some WAG coaches during periods
of rapid growth. Specifically, training was adapted by reducing training load, spending more time doing physical preparation, going back to basic skills and changing the surface for landings with the aim of reducing the risk of injury.

‘...so, identifying, when they are in those, kind of, growth changes and maturation, that loading or planning needs to be, kind of, individualised and changed to ensure the avoidance of injuries, so a link-in to that.’ (TRA Coach 14)

‘I guess tying back to these things, the tracking, so knowing when they’re in growth and then adjusting if you need to adjust, maintaining a good relationship when they’re going through the difficult time.’ (WAG Coach 10)

Across all disciplines, training was also adapted when a gymnast was injured or returning to play, during holidays, following a break and as a result of external stressors such as exams and personal stressors.

Sub theme: Monitoring training. The majority of artistic coaches did not monitor training load. Conversely, the majority of TRA coaches monitored external training loads through diaries. A popular method of monitoring training is through the number of contacts a gymnast makes with the bed. A few TRA coaches additionally monitored the duration of training and the time of flight on the trampoline.

‘So, I’ve started recording the number of contacts in every session for each of the kids that I coach. So, we record the number of contacts and the length of the session so then I’ve got total volume of work they’ve done, and they can divide that by the time that they’re on the trampoline. So, you can see is its high intensity where you’ve got lots of stuff done in a short amount of time or was it more stretched out. But that’s only recently I’ve started recording stuff to that level of detail.’ (TRA Coach 4)

‘I think if we write things that have programmes, the adaptations are shown on the programme. But I don’t record it.’ (WAG Coach 1)

Monitoring growth & maturity in gymnasts

Monitoring growth and maturity in gymnasts varied amongst each discipline. During workshop discussion sessions two MAG coaches explained how they monitored growth using stature and mass. In comparison, many of the TRA coaches monitored growth through regular measurements of stature and mass.

‘I am starting to get more on measuring height and weight more frequently to make sure that I’m keeping a track and I put it into a scatter graph. So, the top ten gymnasts I coach that are (on squad), I track them, and I do that every fortnight, just track to make sure and see what’s going on. Obviously, I can identify when they go through growth spurts, when they’re staying the same and what I can do.’ (TRA Coach 3)

Other methods of identifying changes in growth and maturity described by individual TRA coaches included shoe size, increases in aches and pains and through visual identification. In WAG, a number of coaches monitored growth through regular measurements of stature, with only a couple measuring mass alongside. Additional methods used by individual WAG coaches to identify changes in growth and maturity included menarche, changes in demeanour and visual identification. The coaches that monitored growth by measuring height and/or mass took measurements, on average, once a month.

‘Often when we come up here and someone will say, “She’s grown,” and you can see it when you see them maybe every couple of months a lot more easily than when you’re looking at them every day.’ (WAG Coach 10)

Sub theme: Weight monitoring. Across all three disciplines, the majority of coaches viewed weighing gymnasts in a negative manner. Coaches felt that weight monitoring was a sensitive subject and associated it with eating disorders. In particular it was highlighted by some trampoline coaches that female gymnasts reacted noticeably more to monitoring weight. A couple of coaches emphasised the need for weight monitoring to protect and keep gymnasts safe.

‘Yeah. So I don’t– I don’t really completely agree with the weighing stuff. And I think it’s not good for their brains as well. And the skin fold thing, as well’ (MAG Coach 8)

‘Psychological. We used to. But the other psychological of it. And we had quite a big group of teenagers. And as you said, they were a group. And we tried not to make it a big thing so that they felt comfortable. And then they come running in and be like, oh, I need to go to the toilet. I’ve got to go to the toilet. I can’t be weighed without going to the toilet...’ (WAG Coach 2)

Gymnastics specific scientific and medical knowledge and support

Coaches from all three disciplines discussed the additional scientific and medical support in relation to
gymnastics. Scientific and medical practitioners were recognised for providing advice and support in regard to managing and reducing the risk of injuries.

‘If they get an injury, go to physio. They have a better knowledge. They helped me in that sense and said, “This is why he’s growing. Keep measurements, keep strength testing,” which is always a good thing to do because we basically cover...’ (MAG Coach 2)

‘Lenka, sometimes she’s finished in an hour and then she does some stability work the physio has given her to help with the way her body is growing. There is always other stuff he can find for them to do.’ (TRA Coach 4)

Coaches from all disciplines requested further education on supporting a gymnast during puberty. This included reducing injury risk during the growth spurt and what a training programme should look like during the growth spurt.

‘I think that’s probably, if I’m honest, an area that I need more guidance on. I know they’re all different but more of a base number of how many and when, you know they’re coming to it and through it. Obviously afterwards it’s fine because you know they have to build it up again but it’s the actual doing enough to keep them up there but not too much that you’re hindering, or they might get an injury.’ (WAG Coach 7)

Discussion

Aligned with the current growth and maturity literature, coaches identified key physical changes during puberty such as an increase in stature and body mass, and changes in body composition. In addition, coaches highlighted how these physical changes, alongside functional changes, contributed towards changes in performance. In particular, coaches agreed that this was a period where gymnasts temporarily ‘lost’ or became confused whilst performing skills that they were once able to perform. A temporary disruption in motor skills, often referred to as ‘adolescent awkwardness’, has also been noted in soccer. Although the exact cause of this phenomenon is unclear, it is likely associated with the development of sensorimotor mechanisms or temporary disruption of sensorimotor mechanisms during rapid growth.

In trampolining specifically, the term ‘lost move syndrome (LMS)’ has previously been used when a gymnast loses body position awareness or, awareness and technique of a particular skill. However, LMS has been labelled as a psychological condition and only researched from a psychological perspective but has not been investigated in relation to rapid growth. Although there is no existing literature specifically exploring skill loss in artistic gymnasts during rapid growth, changes in both rotation and postural control during a handstand as a result of growth have been noted in artistic gymnastics.

Alongside a temporary loss or confusion of skill, coaches attributed more emotions to hormones, injuries and the overall changes that occur as a result of maturation. Adolescence is a time where emotions intensify and fluctuate more rapidly. This is due to a combination of physical, biological, social and cognitive changes that occur throughout this period. Additionally, adolescents are more sensitive to social evaluation as the brain continues to mature. The emotions described by coaches may be a result of fluctuating and more intense emotions experienced by adolescent gymnasts combined with sensitivity to social evaluation. For example, a gymnast may become emotional as a result of constructive criticism from a coach.

Research in the field of developmental psychology presents excellent guidance on understanding the psychological changes that occur alongside puberty which is likely to be applicable to adolescent gymnasts.

Coaches perceived gymnasts to portray a lack of motivation and compliance to training throughout adolescence. A lack of compliance and motivation towards training may partly be due to adolescence being a period where adolescents seek autonomy. Autonomy is a key component of intrinsic motivation and self-determined extrinsic motivation alongside relatedness and competence. If an athlete’s autonomy, relatedness and competence needs are not met, intrinsic motivation and self-determined extrinsic motivation is negatively impacted, and athletes are subsequently predisposed to non-self-determined forms of extrinsic motivation (external regulation and introjection) and amotivation (state of lacking intention to act). The described behaviours may be a result of gymnasts feeling a lack of autonomy if coached in a restrictive way.

One of the most commonly believed causes of injury in youth gymnasts was rapid growth. The adolescent growth spurt has previously been associated with injury in youth athletes. Two coaches suggested that a combination of high training loads and growth could be a cause of injury in youth gymnasts. Although there is currently limited evidence, it has been previously suggested that youth athletes are more vulnerable to injuries during growth, particularly when training loads are high and repetitive. Both high training loads and repetition are common characteristics of gymnastics training. Specifically, gymnastics training involves repetition of the same skills and movement.
patterns. Additionally, coaches from the artistic disciplines associated injuries with an increase in the number of routines or skills performed and increasing the difficulty of skills. Consistent with the observations made by coaches, the incidence of injury has been found to increase when training load increases suddenly in youth athletes from other sports. This emphasises the importance of monitoring training load in gymnastics to reduce the risk of injury.

In line with previous research on injuries in youth gymnasts, growth-related injuries such as Osgood-Schlatter’s disease, Sever’s disease, osteochondritis dissecans and stress fractures of the wrist and back were frequently mentioned by coaches. Coaches also described other acute injuries that their gymnasts experienced, which have been previously reported to occur in gymnastics. These included shoulder injuries in MAG gymnasts, lower limb injuries in TRA gymnasts and hamstring strains in WAG gymnasts.

Two primary mechanisms for reducing the risk of injuries were identified from the focus groups: modifying training during growth and prehabilitation. Suggested and/or practiced modifications to training included reducing training load, minimising impact and training skills in a safer scenario i.e., soft surface. It is likely that modifying gymnastics training during growth in these ways will reduce the repetitive forces and loading on an adolescent’s body at a time where it is more susceptible to injuries e.g., weaker growth plates. Training load has been previously modified in youth squash players ‘at risk’ of Osgood-Schlatter’s symptoms. Subsequently, the number of days of training lost because of Osgood-Schlatter’s were reduced. Prehabilitation was also identified by coaches as a mechanism for preventing injuries in gymnastics. Prehabilitation exercises have often been used in sport to prevent injuries, where the evidence around the efficacy and effectiveness of training programmes that reduce the risk of injury are well-established (youth & adult) in other sports. Research around prehabilitation exercises or equivalent training programmes that reduce the risk of injury in gymnastics is, however, limited and largely anecdotal or based on informed opinion.

The majority of coaches from the artistic disciplines did not monitor training load and therefore any modifications or adaptations to training, especially during periods of rapid growth are unclear. It is likely many coaches do not monitor training load in artistic gymnastics because of the complexity of the sport [multiple apparatus, different surfaces, skills vs routines]. On the other hand, the majority of TRA coaches monitored training load through training diaries. While there is no research on measuring training load in trampolining, many TRA coaches monitor the number of contacts the gymnast makes with the trampoline bed. Overall, more research in monitoring training load in gymnastics is required, particularly as monitoring training load can be a useful tool to help inform decision making, and therefore, reduce the risk of injuries.

Many coaches monitored growth and maturity using measurements of stature. In addition, MAG, TRA and a couple of WAG coaches used mass. These measurements were captured, on average, once a month. However, coaches from all disciplines expressed their concerns regarding weighing gymnasts. Monitoring stature and mass is a commonly used method to monitor growth and maturity, where current anthropometries are plotted against growth curves. Height and weight can be collected routinely in youth sport for the purpose of identifying and monitoring the onset and occurrence of the adolescent growth spurt. However, such strategies are limited in that they rely on retrospective analysis. For example, a child may be three-to-six months into their growth spurt before there is any evidence of a change in growth velocity. More recently, stature and mass are often collected alongside other measurements (seated height, parental height, age, sex) to predict when peak height velocity (PHV) will occur. Identifying PHV is particularly important as it is a time when young athletes are at an increased risk of injury. However, it was not clear from the focus groups how the majority of coaches used this information. In line with the literature, menarche and visual identification was additionally identified as a method of monitoring/assessing maturity by some coaches.

Coaches recognised the additional scientific and medical support they received from practitioners, particularly during growth and maturation. Coaches also highlighted the need for further education in relation to supporting a gymnast during puberty. Educating coaches in these areas will likely help reduce the risk of injury alongside burnout and dropout in gymnastics. Other sports have supported the notion of coach education, particularly as a means of reducing the risk of injury.

Although the study incorporates a number of gymnastics coaches across three disciplines [MAG, WAG, TRA], the findings cannot be generalised for all gymnastics coaches. The findings in this study are relative to coaches working with young, competitive, artistic and trampoline gymnasts in Great Britain, however identified considerations can be useful across disciplines and sports, particularly in terms of monitoring training load and growth for reducing the risk of injury. From a methodological standpoint, an appropriate number of focus groups were completed to reach data saturation.

The findings in this study show the current knowledge, awareness and practice of coaches regarding
growth and maturation, and training load in competitive, young gymnasts. The study highlights the need for more coach education around the monitoring of growth and maturation, and training load. Education in these areas will aid coaches in their coaching practices and subsequently contribute to reducing the likelihood of overtraining syndrome, burnout and dropout alongside reducing the risk of injuries in young, competitive gymnasts. More coach education is also required in regard to coaching and supporting a gymnast during puberty. Additionally, the study emphasises the need for further research regarding monitoring training load in artistic and trampoline gymnastics.

In conclusion, coaches were aware of physical changes and injuries that occur during the adolescent growth spurt. In addition, psychological changes and temporary skill loss/confusion were identified as significant during this time. The knowledge and practice of monitoring growth and maturation, and training load did however differ between disciplines. Finally, sports science and medicine practitioners were recognised as key stakeholders in helping manage and reduce the risk of injuries during growth. More coach education and research are required around monitoring training load and growth to aid coaching practice and therefore reduce the risk of injuries in young, competitive gymnasts.

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Appendix 1. COREQ (COnsolidated criteria for REporting qualitative research) checklist.21

| Topic | Item no. | Guide questions/description | Reported on page no. |
|-------|----------|----------------------------|---------------------|
| **Domain 1: Research team and reflexivity** | | | |
| **Personal Characteristics** | | | |
| Interviewer/facilitator | 1 | Which author/s conducted the interview or focus group? | 2 |
| Credentials | 2 | What were the researcher’s credentials? E.g. PhD, MD | 2 |
| Occupation | 3 | What was their occupation at the time of the study? | 2 |
| Gender | 4 | Was the researcher male or female? | 2 |
| Experience and training | 5 | What experience or training did the researcher have? | 2 |
| **Relationship with participants** | | | |
| Relationship established | 6 | Was a relationship established prior to study commencement? | 2 |
| Participant knowledge of the interviewer | 7 | What did the participants know about the researcher? e.g. personal goals, reasons for doing the research | 2 |
| Interviewer characteristics | 8 | What characteristics were reported about the interviewer/facilitator? e.g. Bias, assumptions, reasons and interests in the research topic | 2 |
| **Domain 2: study design** | | | |
| **Theoretical framework** | | | |
| Methodological orientation and Theory | 9 | What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis | 2 |
| **Participant selection** | | | |
| Sampling | 10 | How were participants selected? e.g. purpose, convenience, consecutive, snowball | 2 |
| Method of approach | 11 | How were participants approached? e.g. face-to-face, telephone, mail, email | 2 |
| Sample size | 12 | How many participants were in the study? | 2 |
| Non-participation | 13 | How many people refused to participate or dropped out? Reasons? | 2 |
| **Setting** | | | |
| Setting of data collection | 14 | Where was the data collected? e.g. home, clinic, workplace | 2 |
| Presence of non-participants | 15 | Was anyone else present besides the participants and researchers? | 2 |
| Description of sample | 16 | What are the important characteristics of the sample? e.g. demographic data, date | 2 |
### Appendix 1. Continued.

| Topic                      | Item no. | Guide questions/description                                                                                                                                                                                                 | Reported on page no. |
|---------------------------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|
| **Data collection**       |          |                                                                                                                                                                                                                             |                      |
| Interview guide           | 17       | Were questions, prompts, guides provided by the authors? Was it pilot tested?                                                                                                                                               |                      |
| Repeat interviews         | 18       | Were repeat interviews carried out? If yes, how many?                                                                                                                                                                      |                      |
| Audio/visual recording    | 19       | Did the research use audio or visual recording to collect the data?                                                                                                                                                        |                      |
| notes                     | 20       | Were field notes made during and/or after the interview or focus group?                                                                                                                                                   |                      |
| Duration                  | 21       | What was the duration of the interviews or focus group?                                                                                                                                                                     |                      |
| Data saturation           | 22       | Was data saturation discussed?                                                                                                                                                                                              |                      |
| Transcripts returned      | 23       | Were transcripts returned to participants for comment and/or correction?                                                                                                                                                  |                      |
| **Domain 3: analysis and findings** |          |                                                                                                                                                                                                                           |                      |
| Data analysis             |          |                                                                                                                                                                                                                           |                      |
| Number of data coders     | 24       | How many data coders coded the data?                                                                                                                                                                                        |                      |
| Description of the coding tree | 25   | Did authors provide a description of the coding tree?                                                                                                                                                                       |                      |
| Derivation of themes      | 26       | Were themes identified in advance or derived from the data?                                                                                                                                                                 |                      |
| Software                  | 27       | What software, if applicable, was used to manage the data?                                                                                                                                                                   |                      |
| Participant checking      | 28       | Did participants provide feedback on the findings?                                                                                                                                                                           |                      |
| Reporting                 |          |                                                                                                                                                                                                                           |                      |
| Quotations presented      | 29       | Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number                                                                                             |                      |
| Data and findings consistent | 30   | Was there consistency between the data presented and the findings?                                                                                                                                                         |                      |
| Clarity of major themes   | 31       | Were major themes clearly presented in the findings?                                                                                                                                                                       |                      |
| Clarity of minor themes   | 32       | Is there a description of diverse cases or discussion of minor themes?                                                                                                                                                     |                      |
Appendix 2. Focus group guide.

| Stage of Focus Group | Content |
|----------------------|---------|
| Introduction         | Let’s start by introducing ourselves: What’s your name? What club are you based at? Why did you become a gymnastics coach? Before we begin the first task, I’d like to encourage you all to be as open and honest as possible, try to avoid speaking over each other and to respect each other’s opinions. As this is a focus group, discussion amongst each other is encouraged. If there is anytime you do not wish to answer a question or feel uncomfortable, please don’t hesitate to let me know. Equally if you don’t understand a question, please ask, I’m happy to expand. Does anyone have any questions before we begin? |
| Task 1               | So, in front of you, there should be a pad a pen. Can you write down 3 things that come to mind when thinking about growth and maturation of gymnasts? As a group I would like you to cluster into themes, its ok if some don’t fit. |
| Feedback of Task 1   | *Let’s have a look at the type of things you’ve come up with *Link to first question |
| Growth/Maturation    | • What are the changes that you notice when a gymnast is growing? • Do these changes present challenges to you as a coach? – How is it challenging? – How do you manage them? What would help you overcome these challenges? |
| Training Load        | The next questions will around the subject of training • How much training is required for a gymnast who is on the [SPECIFIC PROGRAMME]? – Why? – What does this include? – Does the volume or intensity of training ever change? – Can you think of any other times when there are changes? – Do you currently track these changes in training? – How? What is the reason behind doing/not doing this? – How does training compare to gymnasts on [X SQUAD]? • Does training present any challenges to you as a coach, in gymnasts who are growing? – What are these challenges? – How do you manage them? What would help you overcome these challenges? |
| Injuries             | The final couple of questions will be around the topic of injury • Is there a period where gymnasts seem to become injured a lot more than usual? – Why do you think this is? – What type of injuries? • As a coach what can be done to reduce the chances of these injuries from occurring? |
| Final Question       | • We have come to the end of the focus group, is there anything we haven’t touched upon that you would like to discuss? |
### Appendix 3. Supporting quotes.

| Theme (Sub-theme) | Definition |
|------------------|------------|
| Physical changes during growth/maturation | ‘Well, you do get injury, because the body is upside down and the weight-to-power ratio is not where it needs to be.’ (WAG Coach 13)  
‘And that’s where, like, it’s so, so different, because the boys just get stronger, and all of a sudden they are jumping higher.’ (TRA Coach 16)  
‘I was going to say, the only thing we’ve really said I think was you said with skill confusion, it can become a challenge obviously that they don’t really know where their body is as much. Their hand was here but now it’s out here. So, they realise that it’s just about getting used to where their body is again.’ (TRA Coach 7)  
‘Often you find times when skills that they’ve been able to do for a long time and/or relatively easily, suddenly they lose, don’t they? I suppose its management on our behalf as to how we can help them understand that and manage that and not then get too emotional about it because then that adds another factor of loss of control. That would be what I’d say about skills and losing skills.’ (WAG Coach 6)  
‘Yeah, it’s like what we spoke about, because they can go from one week doing all these skills to the next where they can’t do any of those skills. That’s what I’m saying. That’s where it becomes a challenge, because you’re then playing the role of getting them to understand. He could do this, but now he can’t. You know they’re growing, but you think, has it affected them that much? You’ve got to, then, understand in your own head, but then also help the gymnast.’ (MAG Coach 7) |
| Temporary skill loss/confusion in youth gymnasts | ‘I think with the girls particularly, because I coach mainly girls, at that time of the menstrual cycle it’s important that I know when it’s happening to be able to explain to them the reasons that they might be getting frustrated or getting upset, particularly if it’s new and they’re just reaching that stage. We’ve gone through times where we’ve had performers cry and then you’ll ask what they’re crying for and they don’t know. So, they’re not necessarily aware of why it’s happening and how their body is changing.’ (TRA Coach 1)  
‘I do a lot less coaching now and a lot more mind games, just trying to get them to do the work. It is a total mind game. That’s what I’ve found really hard, especially recently. Before they hit 11/12, they basically do exactly what you ask of them, don’t they? Then something happens and boom, they get an attitude.’ (MAG Coach 2) |
| Psychological challenges in pubertal gymnasts | ‘Maybe do we rush it a little bit too soon or have too many hours so then their bodies are taking too much on when they’re too little and they are growing, all these different things. It’s a very fine line, isn’t it, between what is expected of them and being able to do enough hours to achieve that and then sustain it through puberty and then beyond and then have more.’ (WAG Coach 7)  
‘Then when their skill level increases, they’ve obviously got more risk of catastrophic things, haven’t they?’ (WAG Coach 8)  
‘And a lot of that is down to physical ability, being too heavy, not being strong enough, or weight-to-power ratio not being where it needs to be, or you’re asking a gymnast to do a skill which is beyond their capability for the strength and flexibility that they have got.’ (WAG Coach 8)  
‘Yeah, it’s just basically they’re growing more frequent injuries because landings and stuff, the muscle’s growing away from the bone, Osgoods schlatters stuff like that. Growth plates. You’ve just got to be more careful with it when they’re having a growth spurt and stuff like that because they’re prone to it.’ (MAG Coach 10) |
| Injury in youth gymnasts | ‘It’s very much around where gymnasts are starting to go through that growth period, and they might be starting to get overloaded, and then suddenly they have got niggles in their knees, or they’ve got niggles in their ankles, and, you know, stuff like that.’ (TRA Coach 12) |
| Sub theme: Injury causes | |
| Sub theme: Injury types | |
Appendix 3. Continued.

| Theme (Sub-theme) | Definition |
|------------------|------------|
| **Sub theme: Injury prevention** | 'Severs, Osgoods, growth plates in the wrist, stress fracture in the elbow, stress fracture in the back. That's gymnasts, that's their injuries.' (MAG Coach 8) 'Going through puberty I suppose you get lots of hamstrings, the Sever's, the Osgood-Schlatter, don't you, a lot of that.' (WAG Coach 7) 'We're talking about injuries going through growth and stuff that can't be prevented. But a lot of stuff with the right balance and the right proactive approach, you can reduce the risk of these injuries.' (MAG Coach 9) 'I just think it's very important as coaches that we're aware of the dose of training when physical changes are happening within the body, especially when they're at peak growth velocity, you've got to adapt training in order to stay away from getting injuries and then having to take time out of training. So, an appropriate dose of training at varying times throughout maturation...' (TRA Coach 6) 'Rehab type stretch. If you know that weak glutes can be a contributing factor to causing stress in ankles for example, having a programme that involves glute exercises in advance.' (TRA Coach 7) 'Good communication so the gymnasts have to tell you when their knees are getting sore or their heels are getting sore so then you know...' (WAG Coach 9) |
| **Sub theme: Programmed training** | 'Then you've got to then put in your rehab stuff or your core strength, your handstand. It's just masses of stuff that the kids need to do. The volume that they have to do is crazy. You need that time to do it.' (MAG Coach 2) 'Straight out of the competition I keep the momentum going for a day or two where they're either motivated by loss or win so I keep that going, give them a couple of days off and then I drop them off load and give them a couple of days off so like an off load and then build them back up again. That's how I work my programme.' (TRA Coach 3) |
| **Sub theme: Adapting training** | 'I had quite a lot of kids this year. Was it this year? What year is it when you do SATs? Is it Year 6 when you're ten? So, I had quite a few kids that had SATs this year or last year, I can't remember. I ended up just giving them time off training or just adapting training and letting them come in when they wanted to on that week of exams because otherwise, they would just stress with trampolining and stress with exams. It just didn't work out for them. So, during that period of time, I think it's important to let them go and do their thing as well. Also, I've got athletes that are verging into senior now. I've got one gymnast who's turning 18 and he's on the GB team for DMT. I adapt his training quite a lot to his personal life, which I've not ever had to do before because I've never had a gymnast that age before, a good gymnast that age.' (TRA Coach 3) 'I think when they're coming back from injury as well, you've got to obviously be careful at that point how much you do. And we're now about six months out of an injury. And we're still having to be careful in the numbers and the reps that we do because we don't want it to set her back again. And even if it's not an injury, even if it's just something small that's hurting, that's when the load changes again.' (WAG Coach 2) 'I think at New York, we get up to-- I don't count it, but perhaps 30 hours when the kids are off of school, like at half term and stuff. They'll get up to about 30, the top athletes.' (MAG Coach 6) |
| **Sub theme: Monitoring training** | 'Does everybody's kids have a diary?' 'So that's a good way for tracking exactly what they're doing. Mine write in what they've done that day, how long the session has been. I think that's an easy way of tracking.' (TRA Coach 1) 'Just like measuring them once, a couple of times a month, maybe. Just to keep, like you said, keep a look at the height. Like you said, you would then realise you should maybe go off that.' (MAG Coach 7) 'We measure ours monthly, so we've got a record of their height.' (WAG coach 8) |
Appendix 3. Continued.

| Theme (Sub-theme)                      | Definition                                                                                                                                                                                                 |
|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Sub theme: Weight Monitoring**      | ‘I just think you’ve got to be sensitive around it because obviously we don’t want to end up with athletes that have got eating disorders and things, to put it on the table and be blunt.’ (TRA Coach 6) |
|                                       | ‘I think that was evident with the girls at the last squad. The girls and boys very much differed when it came to getting weighed. The girls were very much around and having a look what everybody was, whereas the boys weren’t so bothered by it. But in the back of the girls’ heads, you could see it was, “She weighs this.” So, I think it’s making sure you sit down and explain, “You’re a foot and a half taller than her. It’s only natural that you are going to weigh more. It doesn’t matter what kind of weight it is. It’s not necessarily unhealthy weight.” I think that’s important as well because I do think it’s a big focus, particularly among the girls that are 1,2,3,4 years old.’ (TRA Coach 1) |
|                                       | ‘I think, possibly, some coaches, maybe they don’t like doing that. You know, kids on scales... but it’s, like... I think we’ve got a duty of care to do that, to make sure that we are identifying very quickly that, if someone has got a critical growth spurt, we are...’ (TRA Coach 6) |
|                                       | ‘I think gymnastics is in a very tough situation, in the fact that weight is very important to keep them safe, but we are not in a weight class sport.’ (WAG Coach 11)                                                                                      |
| Gymnastics specific scientific and medical knowledge and support | ‘Physiotherapy. We’ve got a physiotherapist who comes in for two hours. She alternates each week. She will go through, like for example I’ve got one little girl who is like, “My ankle hurts a bit,” and it’s like, “Right, we’ll get the physio.” She checked her and one leg is longer than the other. So, she gave her a few exercises and then will check her again in a couple of weeks and see if it’s reduced the ankle pain, if it’s helped things like that.’ (TRA Coach 7) |
|                                       | ‘So, we’re quite fortunate—well, I am anyway, in where the sport science, and you’ve got access to all of that. Like, when he sends the weight back, he’ll put she’s near peak velocity, or something like that.’ (WAG Coach 3) |
|                                       | ‘That could be centralised to our sports specific. I know that everyone is different as you say, it’s different injury, different rates, different heights and sizes but there’ll be some common guidance available, here’s some things to look out for and here’s what you can do about it, swap squats for this, if they’re growing, etc.’ (TRA Coach 5) |
|                                       | ‘But maybe in these stages it might be worth reducing. This is what we could be educated in. That would be helpful because mine I know are starting to go through this and they’re still doing exactly the same training hours, pretty much the same programme or expected to do a similar programme. I’ve not really adapted it that much, apart from applying some prehab programmes and the conditionings being adapted.’ (MAG Coach 2) |