Evaluation of physical and psychological differences for age, gender and discipline in elite gymnasts in Iceland

by

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Thesis of 60 ECTS credits submitted to the Sports Science Department, School of Social Sciences at Reykjavík University in partial fulfillment of the requirements for the degree of

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Main supervisor: Jose M. Saavedra

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Líkamlegur og andlegur munur á aldri, kyni og grein hjá íslensku landsliðsfólki í fimleikum

Markmið þessarar rannsóknar var að: (1) meta mun á líkamssamsetningu og líkamlegum þáttum eftir aldri, kyni og grein; (2) meta mun á sálfræðilegum þáttum eftir aldri, kyni og grein; og (3) meta mun á frammistöðu á þrekprófi fyrir og eftir keppnistímabil hjá íslensku landsliðsfólki í fimleikum. Aðferð: áttatíu og sex manns úr áhaldafimleikum karla og kvenna, og hópfimleikum tóku þátt í rannsókninni. Frammistöðuprófin the Men‘s Gymnastics Functional Measurement Tool og the Gymnastics Functional Measurement Tool voru notuð. Þrír spurningalistar í sálfræði voru lagðir fyrir: the Test of Performance Strategies Questionnaire, the Sport Mental Toughness Questionnaire og the Sport Anxiety Scale–2 Questionnaire. T-próf óháðra úrtaka var notað til að bera saman hópa og parað t-próf til að reikna út mun á milli endurtekinna mælinga. Niðurstöður líkamsmælinga: eldra fær fleiri stig en yngra í öllu nema armbeygjum. Karlar eru með meiri styrk en konur, en konur eru með meiri liðleika. Iðkendur áhaldafimleika eru betri í hangandi styrk og liðleika en iðkendur hópfimleika sem eru með meiri gripstyrk og hlaupahraða. Niðurstöður sálfræðimælinga: eldra notar frekar virkjun en yngra, sem notar frekar sjónmyndun. Konur nota meira sjálfstal á æfingu en karlar, iðkendur hópfimleika nota meiri tilfinningastjórnun á æfingu en iðkendur áhaldafimleika. Karlar hafa betri stjórn en konur, sem hins vegar sýndu meiri einbeitingatruflun og áhyggjur. Yngra landsliðsfólk upplifir frekar truflun á einbeitingu en það eldra. Liðleiki og jafnvægi mældist minna eftir keppnistímabilið en fyrir. Ályktun: gagnlegt væri fyrir afreksfimleikafólk að halda líkamlegum styrk út keppnistímabilið og bæta þjálfun á sálfræðiþáttum inn í æfingaáætlunina.

Leitarorð: Fimleikar, áhaldafimleikar, hópfimleikar, þrekpróf, sálfræðilegir þættir, frammistöðumælingar.

Abstract

Evaluation of physical and psychological differences for age, gender and discipline in elite gymnasts in Iceland

The objectives of the present study were: (1) to evaluate the difference in anthropometry, body composition, and physical fitness concerning age, gender, and discipline; (2) to evaluate the difference in psychological skills in terms of age, gender, and discipline; and (3) to identify the impact that the competition period had on physical measurements of elite gymnasts in Iceland. Methods: Eighty-six gymnasts from three gymnastics disciplines; Women's artistic gymnastics, Men's artistic gymnastics and TeamGym, participated in the study. The physical tests were: The Men‘s Gymnastics Functional Measurement Tool and The Gymnastics Functional Measurement Tool. Three questionnaires were on offer: the Test of Performance Strategies Questionnaire, the Sport Mental Toughness Questionnaire, and the Sport Anxiety Scale–2 Questionnaire. The Independent samples t-test was used to compare groups and the Paired samples t-test to compare pre-and post-measurements. Physical results: Seniors scored higher than juniors in all except push-ups. Males had more strength than females, who had more flexibility. Artistic gymnasts had more hanging strength and flexibility than TeamGym, who had more grip strength and speed. Psychological results: seniors had more activation than juniors, who had more imagery. Females used more self-talk in practice than men and TeamGym showed more emotional control in practice than Artistic. Male showed more control than females, who showed more worry and concentration disruption. Juniors show more concentration disruption than seniors. Post-competition period flexibility and balance was less than pre-competition. Conclusion: Maintaining physical abilities during competition period and training psychological skills might benefit elite Icelandic gymnasts.

Keywords: Icelandic gymnastics, Artistic gymnastics, TeamGym, Physical test, psychological skills.

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I would like to thank the Icelandic gymnastic federation for giving me the opportunity to do these measurements with the Icelandic national teams. Gymnastics have been my hobby and part of my career most of my life, first as a gymnast, then as a club coach, international judge, national coach, and physiotherapist. It was terrific to work with the national teams who took part in this project with a positive attitude and their competitive spirit. I treasure the cooperation with the federation's staff, Sólveig Jónsdóttir, Íris Mist Magnúsdóttir, and Sæunn Viggósdóttir, who helped with contacting gymnasts and coaches, finding venues, and due to Covid-19 had to rearrange the measurement dates three times in 2020 and 2021.

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List of Abbreviations

FIG	Fédération Internationale de Gymnastique
GFMT	The Gymnastics Functional Measurement Tool
MAG	Men's artistic gymnastics
MGFMT	The Men‘s Gymnastics Functional Measurement Tool
PHV	Peak Height Velocity
PSV	Peak Strength Velocity
SAS-2	Sport Anxiety Scale 2 Questionnaire
SMTQ	Sport Mental Toughness Questionnaire
TG	TeamGym
TOPS	Test of Performance Strategies
UEG	European Union of Gymnastics
WAG	Woman’s artistic gymnastics

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1 Extended literature review

1.1 Gymnastics

Gymnastics originate from ancient Greeks who envisaged it as a perfect symmetry between mind and body and a celebration of physical fitness. In the early 1800s, the Greek military used gymnastics in training to better prepare the soldiers for warfare. The German Friedrich Ludwig Jahn is considered the father of Modern gymnastics as we know the sport today. Jahn inaugurated the open-air gymnasium, the Turnplatz, in Berlin in 1811 and introduced many of the basic routines still used today. He helped develop a sport that combines physical strength, explosion of power, artistry at optimum speed, coordination and flexibility of the body that results in a performance that can be easily argued celebrates the human spirit (*Friedrich Ludwig Jahn*, n.d.).

1.1.1 Gymnastic disciplines

The International Gymnastic Federation (FIG) has eight different disciplines. Gymnastics for all, men's artistic gymnastics, women's artistic gymnastics, rhythmic gymnastics, trampoline gymnastics, acrobatic gymnastics, aerobic gymnastics, and parkour, the latest addition (*FIG Gymnastics Website*, n.d.). FIG was founded in 1881, making it the world's oldest international sports organization. Artistic gymnastics have been contested in the Olympics since the modern inaugural games in 1896. The trampoline competition made its debut in 2000 for both men and women, and rhythmic gymnastics became a women's event for the first time in 1984 (*International Gymnastics Federation*, n.d.).

The European Gymnastic Federation (UEG) formed in 1982 as the European Union of Gymnastics has the same disciplines as FIG but offer TeamGym instead of FIG's Parkour. (*European Gymnastics*, n.d.).

The Icelandic Gymnastic Federation (FSÍ), founded in 1968, is a part of FIG and UEG. In Iceland, there are five disciplines in gymnastics: Gymnastics for all, men's artistic gymnastics, women's artistic gymnastics, parkour, and TeamGym. Artistic gymnastics and TeamGym are a competitive sport with national teams competing and general gymnastics is a recreational sport (FSÍ, n.d.) Artistic gymnastics is an individual sport, while TeamGym is a team sport with 6–12 members. The events in TeamGym include tumbling, trampette, and floor program and are the same for males and females, while in artistic gymnastics, the events differ for genders (Harringe et al., 2007).

1.1.2 Artistic gymnastics

Men’s and women's artistic gymnastics are two sports, with different apparatus, rules, and judge’s license. Opposed to many other sports that often determine competitive levels by age or size, artistic gymnasts compete according to levels of individual capacity. Most sports, can be performed with varying degrees of skill at the early stages of development, but gymnastics usually require years of training before the gymnast can perform routines that suffice in even the lowest levels of competition (Sands et al., 2002).

1.1.2.1 Women’s Artistic Gymnastics (WAG)

Women’s Artistic Gymnastics (WAG) is one of the most popular, celebrated, and thoroughly modern sports for women, having undergone more transformation than any other Olympic sport. With a thrilling combination of daring and grace, gymnasts perform challenging elements on four apparatus, emphasizing agility, artistry, flexibility, power, and style.

Vault is the fastest event and features gymnasts propelling themselves over a vaulting table at full sprint, flipping or twisting back or forward to land on the mat. In uneven bars gymnasts swing on two asymmetric bars, frequently releasing the bar and recatching it. In contrast, the balance beam involves tumbling, acrobatics, choreography, and dance elements on a narrow beam only 10 cm wide. Floor Exercise is the only event set to music and features tumbling, leaps, turns, and choreography on a spring-loaded mat. In all events, gymnasts are judged on the difficulty of the exercise, execution, as well as dynamics, including height and distance from the apparatus, and must show strength, flexibility, balance, and rhythm (FIG, n.d.-b).

1.1.2.2 Men’s Artistic Gymnastics (MAG)

In Men’s Artistic Gymnastics (MAG), the gymnasts display superhuman strength as they challenge gravity and push the limits of physics in six separate events: Floor Exercise, Pommel Horse, Still Rings, Vault, Parallel Bars and Horizontal Bar.

Floor Exercise features tumbling and other acrobatic elements on a specially created mat. The Pommel Horse requires gymnasts to display circles, flairs, and other swinging elements above the horse. The Still Rings test endurance and strength, with the athletes supporting themselves and performing complex holds with their arms. Vault, one of two power events along with Floor Exercise, is the fastest event and features gymnasts propelling themselves over a vaulting table at full sprint. Parallel Bars and Horizontal Bar are both swinging events with frequent releases and a big dismount.

In all events, gymnasts are judged on the difficulty of the exercise, execution, dynamics, including height and distance from apparatus, and must show strength, flexibility, and balance (FIG, n.d.-a).

1.1.3 Team Gym (TG)

The European Championships in TeamGym (TG) is one of the youngest European gymnastics events and have been conducted biannually since 1993 (Elbæk, 1993). The first European Gymnastics TeamGym competition was the then-called Euroteam held in Finland in 1996 and the first official TeamGym European Championships took place in Sweden in 2010, where junior teams were included (*European Gymnastics*, n.d.).

TeamGym is a team competition performed in three disciplines: floor, tumble, and trampette. All three apparatuses require effective teamwork and excellent technique with complex skills in acrobatic and gymnastic elements. The TeamGym floor program involves choreography to music lasting between 2min 15s and 2min 45s and includes flexibility movements, jumps, acrobatics and balance elements. The tumbling routine comprises a tumbling track with a run-up of 16 meters, where the gymnasts perform a series of acrobatic elements backward and forwards. The trampette routine involves a square-formed mini trampoline to which a 25m run is required. The gymnasts perform somersaults with and without a vaulting table. In addition to physical fitness, all three routines require high technical skills. TeamGym competitions are divided into three sections: Women, Men, and Mixed teams. The event is attractive for spectators, media and sponsors as it is both entertaining and exciting to watch. TeamGym competitions are recognized for their excellent spirit and dynamic atmosphere (Sjöstrand et al., n.d.).

TeamGym is a new and popular form of gymnastics originating from Scandinavia. TeamGym attracts the highest number of gymnasts among the disciplines in Sweden, and the sport is rapidly spreading in Europe. The sport differs in several ways from the most known form of gymnastics, Artistic gymnastics. Each event in TeamGym is performed by the team members simultaneously. The entire team participates in the floor program. Three series of tumbles and three different vaults are performed by at least six team members in a row one after the other, and the team receives a total score for each event (Harringe et al., 2007).

A team may consist of eight to ten gymnasts, all of whom compete on the floor. In tumble and trampette, six gymnasts perform in each round. All the performing gymnasts are judged. A mixed team consists of 50% male and 50% female gymnasts (Sjöstrand et al., n.d.).

The performance during competition is brief; a tumble lasts for approximately seven seconds per gymnast. The three rounds of tumbles performed by the team last for approximately three minutes, but gymnasts spend much more time in the gymnasium to prepare for these few minutes of maximum effort (Lund & Myklebust, 2011).

1.1.4 Evaluation of gymnastics

Historical gymnastics fitness profiles over several decades have shown that the demands on gymnasts have increased in parallel with the progressive rules changes as established by the gymnastics Code of Points that is the judge's rule book and, without being a gymnastics coaching manual, drives much of gymnastics training (Jemni et al., 2000; W. A. Sands, 2000).

The first unique instructions FIG gave for evaluating exercises in artistic gymnastics was the Code of Points, created in 1949 and reviewed and updated every four years (UEG, 2017). The difficulty value of the exercise is determined according to the content and difficulty of the routine. The Code of Points' primary purpose and goal is the provision of a more objective evaluation of exercises (FIG MAG, 2017; FIG WAG, 2017). Independent members of the Apparatus Jury are on all apparatus. The D panel evaluates difficulty, special requirements and bonus points, and the assessment starts from 0.0 points. The E panel evaluates the performance of an exercise, technique, body posture and balance and provides deductions for the performance from 10.0 points. D panel determines the initial assessment of an exercise. The E panel registers performance errors due to technical performance, body posture, and balance of exercise performance. Those two grades combine to provide the final grade (Atiković, 2013).

In TeamGym, E and CD judges apply the rules of the Code of Points to evaluate each round. A combined final score of the floor program and the three different rounds in the tumbling and trampette routines rank the team in a competition (Myrian et al., 2019; Sjöstrand et al., n.d.). The difficulty values for all elements in the competition routines are identical for females and males in the Code of Points. Due to the significant differences in physical performance, this can be an obstacle for female competitors (Höög & Andersson, 2021).

Each country uses the Code of Points for international competition and often modifies the international rules for lower-level domestic competitions and training. The Code of Points changes almost continuously via rule interpretations, with considerable changes occurring at least following each Olympiad. The emphasis on flexibility was more prominent in earlier Codes. The current demands of gymnastics require less emphasis on extreme ROMs in poses, postures, and skills while increasing the physical demands for strength and stability of the spine (W. A. Sands et al., 2016).

1.1.5 Age changes

The age for elite competitors in artistic gymnastics has been changing over the last 30 years. In Artistic Gymnastics in the 50s and 60s, the senior competition was dominated by athletes in their mid to late twenties. The Code of Points was aimed more towards artistry and inspired mainly by movements from ballet. As a result, more seasoned gymnasts found success in the sport by bringing elegance to their routines. Before 1981 top gymnasts were between 20 and 30 years old when winning Olympic and World championships. In the 1970s, the average age began to decrease gradually. After the 1992 Olympics, when the best gymnasts were getting younger, the FIG changed the age limit from 14 to 15 and to 16 in 1997. The age changes were done for health reasons such as musculoskeletal development of young competitors, lengthening gymnastics careers, preventing burnout, and countering negative publicity that the sport has received (Anderson, 1997).

Since 1997, the FIG has gradually changed the regulation for participation in a world championship. First, the gymnasts had to be at least 16 years og age or turning 16 within the calendar year to participate as seniors. Today, the limit sits at 18 for male gymnasts and 16 for women gymnasts (Atikovic, 2020; W. A. Sands et al., 2002).

The proportion of young and tiny gymnasts performing in elite gymnastics has lowered in the last decade, with a significant number of older gymnasts now competing successfully at elite level. For example, in the 2014 World Championships, 29.4% of the gymnasts were aged over 20, and the mean average of WAG competitors has increased from 17.6 in the 2000 Olympic Games to 20.29 in the 2016 Olympic Games (R. Kerr et al., 2018).

The term senior in gymnastics refers to any world-class gymnast who is age-eligible under FIG rules. The term junior describes any gymnast who competes at a world-class level but does not meet the FIG's age minimum. Juniors are judged under the same Code of Points as the seniors and often exhibit the same level of difficulty in their routines (W. A. Sands et al., 2002).

1.2 Athletic development

The long-term athletic development (LTAD) model was developed to maximize athletic potential. Such models propose "windows of opportunity" that are periods within a child's development where a heightened sensitivity to training adaptation is possible in response to a correct training stimulus (Viru et al., 1999). The LTAD model principally distinguishes four stages of training development that account for enhancing general athletic capabilities and sport specialization after pubertal changes: Fundamental phase, Training to train phase, Training to compete phase, and Training to win phase. British Gymnastics (2005) has developed a Model of LTAD with six progressive stages that apply across each gymnastics discipline. The fundamental first stage is for development of children up to eight years old and is designed to encourage them to become physically active and develop movement skills they need whether they choose to participate in gymnastics, other sports or pursue an active lifestyle. The training to train stage is divided into two age groups, first for seven to nine year olds where primary specialization begins, and multilateral physical preparation leads to low-level competition. Up to ten hours of training per week is usual but slightly more within the early specialization disciplines. The second age group is for ten to thirteen year olds. This stage involves specialized physical preparation with usually around 15 or more training hours. Training to compete stage requires physical preparation, advanced skills, and participation in junior-level competitions. They normally train up to 20 hours per week. Training to win stage involves advanced physical preparation, attainment of high-performance levels of complex skills, and participation in senior-level competitions. They train up to 25 hours per week. The last stage is the retainment stage, where the gymnast maintains the level of physical preparedness, refined skills and routines, at a high-performance level.

The gymnast may also seek to develop other skills such as coaching, judging or officiating as an extension to their career, usually training up to 25 hours per week (British Gymnastics, 2005). It has been argued in Wales Gymnastics (2011) that these models were not introduced to the coaches or they first heard of them during the senior level coaching qualification, so the model was not beneficial.

The LTAD's "windows of opportunity" are different for boys and girls. The first occurs at approximately 7-9 years og age in both boys and girls, with a second window between 11-13 in girls and 13-15 in boys. The fact that the second window is staggered by two years between girls and boys can be interpreted as more maturational than a chronological "window of opportunity" (Balyi & Hamilton, 2004).

The optimal period for strength training is 12-18 months following peak height velocity for boys, but for girls, immediately after peak height velocity or at the onset of the menarche (Balyi & Hamilton, 2004). However, evidence is limited in examining the optimal window of trainability. There are no longitudinal strength training studies that have determined peak height velocity and are appropriately controlled for growth and maturation. Typically these researches include two windows; one prepubertal with neuromuscular coordination developments and another post pubertal linked to maturity-associated increases in muscle mass and sex androgen concentrations circulation (Viru et al., 1999).

LTAD also positively affects the quality of training and competition by considering factors such as developmental age and sensitive periods of optimal trainability. It builds athleticism, beginning with a foundation of fundamental movement skills and introduces fitness and sport skills at the appropriate developmental age (Balyi et al., 2004)

The LTAD model balances training load and competition throughout childhood and adolescence. As previously suggested, too much focus has been placed upon results rather than assisting optimal development processes (Balyi & Way, 2005; Bompa, 2009). Therefore, current research supporting the LTAD model's optimal “window of trainability” for strength is speculative, with only one study concluding that the strength training response is more significant after puberty. Based on current research, children can undertake strength training as long as the program is designed and supervised by professionals This combines successfully employed training methods and more significant scientific basis for children and adolescents (Balyi & Hamilton, 2004).

Worldwide, as the LTAD model has been advanced, it has been adopted and applied by national governments, and consequently, practitioners for developing children into elite athletes. The model is generic rather than an individualized plan for athletes and is under revision as it is challenging for professionals working with children and adolescents. Pediatric exercise scientists have to question, test, and modify the model. It is unlikely to be accomplished using classical experimental research methodology, but this should not restrain practitioners from collecting valid and reliable evidence (Ford et al., 2011).

1.3 Sport specialization

LTAD is an inclusive framework that encourages individuals to get involved in lifelong physical activity by connecting and integrating physical education programs in the school system with elite sports programs and recreational sports programs in the community. LTAD provides a strong foundation of necessary knowledge in performance and life skills and ensures that all children correctly learn the fundamental movement skills since all children attend school. It also ensures that these skills are introduced during the optimum point in their physical development, before age 11 for girls and age 12 for boys, or more precisely, before the onset of the adolescent growth spurt (Balyi et al., 2013). In Canada, provincial sporting organizations are mandated to create their own sport-specific model inherently in line with the LTAD. The models are a transition from diversification where there is a focus on a number of sports to specialization where there is a year-round commitment to a single sport (Rice et al., 2019).

Gymnastics is one of the fundamental movement skills and basics for physical literacy. These skills provide a gateway for all other sports. In athletics you run, jump and throw. Gymnastics revolve around the ABCs of athleticism: agility, balance, coordination and speed; including dance adds to rhythmic abilities. In swimming you develop balance in a buoyant environment that serves as the foundation for all water-based sports. Skating to perform slip and slide movements on ice, snow or water. Without fundamental movement skills, a child will have difficulty participating in any sport. For example, to enjoy baseball, basketball, cricket, football, netball, handball, rugby and softball, the simple skill of catching must be mastered (Balyi et al., 2013).

Sports can be classified as either early or late specialization. Well-known early specialization sports include artistic and acrobatic sports such as gymnastics, diving, and figure skating. These differ from late specialization sports in that very complex skills are learned before maturation since they cannot be fully mastered if taught after maturation (Balyi et al., 2013). If physical literacy is acquired before maturation, athletes can select a late specialization sport between the ages of 12 and 15 and still have the potential to rise to international stardom (Balyi et al., 2013).

A sensitive period is a broad time frame or window of opportunity when learning a specific skill or developing a specific physical capacity is particularly effective. The entire period of childhood can be viewed as a sensitive period for mastering fundamental movement skills (Gallahue & Donnelly, 2007)

1.4 Growth and development

Children of the same chronological age can differ by several years in their level of biological maturity. Their growth and development result from a complex interaction of genes, hormones, nutrients, and the environments, both physical and psychosocial, in which the individual lives. This combination of factors regulates the child’s physical growth, neuromuscular development, sexual maturation and mental, cognitive and emotional development, and general physical metamorphosis during the first two decades of life (Balyi & Way, 2005).

The terms “growth” and “maturation” are often used together and sometimes synonymously. However, each refers to specific biological activities. Growth refers to observable step-by-step changes in quantity and measurable changes in body size such as height, weight, and fat percentage. Maturation refers to structural and functional changes in the body’s progress toward maturity, such as cartilage change to bone in the skeleton (Balyi & Way, 2005).

LTAD requires the identification of early, average, and late to design appropriate training and competition programs for optimal trainability and readiness. The beginning and the peak of the growth spurt (Peak Height Velocity, PHV) are significant landmarks for LTAD training and competition design (Balyi & Way, 2005).

PHV in girls occurs at about 12 years of age. Usually, the first physical sign of adolescence is breast budding, which appears slightly after the onset of the growth spurt. Shortly after that, pubic hair begins to grow. Menarche, or the onset of menstruation, occurs relatively late in the growth spurt after PHV is achieved. Peak Strength Velocity (PSV) comes immediately after PHV or at the beginning of menarche (usually a year after PHV). PHV in boys is more intense than in girls and, on average, occurs about two years later. Growth of the testes, pubic hair, and penis is related to the maturation process. PSV comes 12 to 18 months after PHV. Thus, there is pronounced late gain in strength characteristics of the male athlete. As with girls, the developmental sequence for male athletes may occur two or more years earlier or later than average. Early maturing boys may have as much as a four-year physiological advantage over their late-maturing peers. Eventually, the late maturers will catch up when they experience their growth spurt (Balyi & Way, 2005).

Currently, most athletic training and competition programs are based on chronological age. However, athletes of the same age, between ages 10 and 16 can be developmentally three to five years apart. That makes chronological age a poor guide to segregate athletes (Borms, 1986).

1.5 Physical demands

Gymnastics is generally characterized as a sport with high levels of strength and power relative to body weight, as well as increased flexibility (Arkaev & Suchilin, 2004). Explosive power and high anaerobic capacity are factors that combine various gymnastic disciplines (Aleksić-Veljković et al., 2016, 2016; Bale & Goodway, 1990, 1990; Elbæk, 1993; Jemni et al., 2000; Jensen et al., 2013; Suchomel et al., 2016). Learning different skills is among the physical demands of gymnastics and considerable upper body strength and incredible flexibility. The intense mechanical loading on gymnasts' bones has provided exciting insight into bone development and stiffness (Bencke et al., 2002; Ford et al., 2011).

Strength and power are emphasized in progression within gymnastics to develop new and increasingly complex skills (Ford et al., 2011). For long-term athlete development, training to build strength and power must begin at a young age to complete the required skills for top competitions and achieve maximal potential (Bencke et al., 2002). Gymnasts must possess sufficient explosive power in the lower limb musculature to perform the multitude of necessary jumping skills while maintaining body control (Jemni et al., 2006; Marina & Jemni, 2014).

The trend toward smaller stature and lighter weights in elite female gymnastics may in part be attributed to natural selection based on the direct biomechanical advantages of a pre-pubertal physique that include increased strength vs. weight ratio, greater stability and decreased moments of inertia. These parameters permit more complex vaults, more effortless swings on uneven bars, more excellent stability on the balance beam, and more incredible spring during floor exercises (W. A. Sands et al., 2002, p. 111).

Vandorpe (2011) underlined the critical role of motor coordination in the search for promising gymnasts, as in every age group, motor coordination was extracted as a discriminating factor and appeared to be crucial in gymnastics. Moreover, it was extracted as the single best predictor for talent at a young age. However, it is clear that in a competitive gymnastic population, sport-specific physical performance, general motor coordination and height measures determine the most critical performance indicators in profiling the gifted elite gymnast. In this scope, it is essential to note that rope jumping, extracted at the age of 7, is likely to require good motor coordination for optimal performance. In agreement with the multidimensional nature of gymnastics, a girl should thus exhibit superior coordinative abilities, a small frame, good sport-specific strength, speed, and flexibility to be selected for inclusion into an elite gymnastics’ development program by expert coaches.

There is a growing agreement that traditional cross-sectional talent identification models are likely to exclude many, especially late maturing, ‘promising’ children from development programs due to sports talent's dynamic and multidimensional nature. A conceptual framework that acknowledges both genetic and environmental influences and considers sports talent's dynamic and multidimensional nature is presented (Vaeyens et al., 2008). In an Italian study by Morucci (2014) the focus is on the athlete’s genes and how to make the most of the gymnast’s talents. The genetic measurements were compared to each apparatus and used to improve training methods and programs for elite MAG gymnasts for the federation.

The TeamGym athletes' physical demands remain largely unknown and are likely influenced by the difference in the discipline and equipment used (Hansen et al., 2019). But many apparatus or equipment are similar to artistic gymnastics and hence demonstrate many of the same gymnastics skills and physical demands (Lund & Myklebust, 2011).

Measuring the Rating of Perceived Exertion (RPE) can be a valuable and inexpensive tool to quantify internal training load in TeamGym. In this Italian study, each session was RPE assessed utilizing the VAS and Borg's CR-10 scale. Coaches could use this instrument to monitor their periodization plan as experienced by the athletes to optimize performances and reduce the risk of overtraining and burnout (Minganti et al., 2010). They were considering that TeamGym athletes might differ in their ability to perform elements with specific difficulty ratings; a valuable and practical method needed to monitor their internal training load correctly to optimize performances (Bompa, 2009; Minganti et al., 2010).

Danish National senior gymnasts were monitored; male, female, and mixed teams gymnasts in 2016. Differences were found between male and female TG athletes for all variables. Males were 11% older, 8% taller, had a 19% greater body mass and 8% lower fat mass than the females. They found no significant difference in the overall training volume. Male athletes demonstrated ~50% greater acrobatic difficulty scores than female athletes (Hansen et al., 2019).

Coaches and practitioners should be made more aware of the importance of training to advance all fitness components throughout childhood and adolescence during non-sensitive periods as well, principally because of different individual maturation development rates and all components are trainable to some extent. This should further help coaches avoid issues around early specialization and optimize the general athletic development of young performers (Ford et al., 2011).

1.5.1 Anthropometry and body composition

Anthropometry, or the measurement of humans, has changed dramatically over the past decades. Traditional linear body measures have gradually shifted to 3D and 4D measures and computer models (Karwowski, 2001). Measuring body composition is important for monitoring training and determines many different components, from bone mass, fat mass and percentage, visceral fat and water (Van Marken Lichtenbelt et al., 2004).

When comparing the anthropometric data of of 184 children of both genders participating either in swimming, tennis, team handball, or gymnastics in a Danish study, gymnasts were the smallest and lightest. Still, they did not differ in Tanner stages among the subgroups (Bencke et al., 2002). According to the anthropometric measures from the European Games in 2015, artistic gymnasts were shorter and lighter than athletes from other sports (Silva et al., 2020).

Children 9 to 11 years old showed specific anthropometric, motor coordination profile and physical fitness in relation to the requirements of their particular sport and had positive influence on the child’s general physical profile. Comparison between adolescent athletes showed clearly that each sport is, to some extent, unique in terms of physical prerequisites (Adam et al., 1993; Claessens et al., 1999).

Generally, children at a young age do not exhibit sport-specific characteristics, but it becomes the exception with a high training volume. It is possible that children have not spent enough time yet in their sport to develop qualities in their chosen field or it could be possible that they do not take individual qualities into account when choosing a sport (Opstoel et al., 2015).

Over the past years gymnasts are becoming taller. Atikovic (2020) made a study on participants from the Olympics from 1996 to 2016. The results showed a significant difference between the male and female gymnasts in body height and weight. On average, the female gymnasts were the tallest in the 2012 Olympic Games, 155.4 cm, and the shortest in the 1996 Olympic Games, 151.8 cm. On average, the male gymnasts were the tallest in the 2016 Olympic Games, 167.1 cm, and the shortest in the 1996 Olympic Games, 166.4 cm. The results showed significant differences between women's artistic gymnastics in body weight and height over a 20 - year period, but there was no significant difference for men's artistic gymnastics.

When comparing height and body mass to that of highly trained individual gymnasts, the present male, and female TeamGym appear to be taller, heavier, and with a higher body fat percentage compared to gender-matched artistic gymnasts (Jemni et al., 2000; Paradisis et al., 2013; Rodríguez et al., 2010). Rodrígues and colleagues (2010) have previously reported that senior male trampoline gymnasts have a higher fat percentage and greater body mass than artistic gymnasts. Possibly small body size in individual gymnastics is beneficial for competitive performance (Bale & Goodway, 1990; Paradisis et al., 2013).

The notion that TeamGym athletes were considerably taller and heavier than reported for artistic gymnasts was explained by differences in equipment and specific performance disciplines. The rebounding equipment in TeamGym may allow the gymnast to use a relatively longer contact time than is possible in artistic gymnastics, which might be beneficial for vertical impulse generation when the body mass is greater than typically seen in artistic gymnasts (Hansen et al., 2019).

American collegiate female gymnasts were a unique population according to anthropometric characteristics. Relative to other college-aged women and other female athletes, gymnasts tend to be shorter in stature, lighter in body mass, and higher in body density. These athletes may be described as having ectomesomorphic body types. They have extraordinarily small skinfolds with disproportionate upper body muscle hypertrophy. Their anthropometric characteristics are unique but in some respects similar to those of competitive bodybuilders and professional ballet dancers (Vercruyssen, 1984).

The increasingly dominant performance of smaller-sized female gymnasts and increased magnitude of training beginning at an early age have prompted public and medical concerns, especially from an auxological perspective. A review was made to determine if gymnastics training inhibits growth of females. Elite level or heavily involved female gymnasts may experience attenuated growth during their years of training and competition followed by catch-up growth during reduced training schedules or the months following retirement. However, a cause–effect relation between gymnastics training and inadequate growth of females has not been demonstrated (D. Caine et al., 2001).

The use of bioelectrical impedance analysis for measuring percentage body fat provides the same reliable information as skinfold measurements with a less invasive method and requires less training. This method is more commonly used for assessment in vulnerable populations such as children and the obese. There are more accurate body composition measurements available, but they require complex, time consuming and expensive equipment like Dual-Energy X-ray absorptiometry (Dexa) or the Hydrostatic Weighing method (Kelly & Metcalfe, 2012).

1.5.2 Strength

Muscular strength is the ability of the body to exert a maximum force against an external object. In its purest sense, it is the ability to exert maximum effort. Muscular strength may be increased through isotonic, isometric, and isokinetic means (Gallahue & Donnelly, 2007, p. 84).

Strength increases in both boys and girls until about the age of 14 years, when it begins to plateau in girls and a spurt is evident in boys. By 18 years there are few overlaps in strength between boys and girls, although this simplistic model utilizing chronological age as a marker for development in strength does not consider the individual timing and tempo of growth and maturation, an issue seen with all the fitness components. The exact age at which gender differences become apparent appear to be both muscle group and muscle action specific and data have indicated that differences in upper body strength between the sexes occur earlier than differences in lower body strength (Gilliam et al., 1979; Round et al., 1999).

Well-designed and supervised resistance training for children and adolescents is considered safe and effective (Christou et al., 2006; Faigenbaum et al., 1996; Falk & Tenenbaum, 1996). Numerous reasons are for recommending resistance training in youths; for enhancement of muscular strength (Stratton et al., 2004), improvements in body composition (Sothern et al., 2000) and motor performance (Christou et al., 2006). Also, for possible reductions of injuries (Faigenbaum et al., 1996). For TeamGym gymnasts, lower body strength was considered to be more important than upper body strength (Höög & Andersson, 2021).

In terms of strength, gymnasts are amongst the strongest Olympic athletes when relative strength is measured in relation to body weight (Paradisis et al., 2013).

1.5.3 Power and agility

Agility is the ability to change direction of the entire body quickly and with accuracy while moving from one point to another (Gallahue & Donnelly, 2007, p. 913).

Power, the ability to perform one maximum effort in as short a time as possible, is sometimes referred to as explosive strength and represents the product of strength times speed, exhibited during jumping, striking, or throwing for distance. The speed of contraction of the muscles involved, as well as the strength and coordinated use of these muscles, determines the degree of power (Gallahue & Donnelly, 2007, p. 91).

Rapid developments in muscular power have been established in prepubescent children between the ages of 5 and 10 years (Branta et al., 1984). These periods of accelerated development are largely attributable to enhanced neuromuscular coordination. A secondary spurt has been associated with the onset of puberty in girls between 9 and 12 years, and in boys between the ages of 12 and 14 years (Beunen et al., 1997) with significant development in leg power at the ages of 14 and 15 (Blanksby et al., 1994). Czech national team gymnasts, both male and female, were evaluated by the Wingate anaerobic test. In addition, body anthropometric and peak power performance were obtained. The result showed that anaerobic performance data was not related to their age and fat-free mass of gymnasts. The study indicates that in relatively homogeneous groups of gymnasts the anaerobic performance may not be dependent on age and body composition (Heller et al., 1998).

As with a number of other physical components, gender-related differences appear to exist in muscular power from pre- to post-adolescence, with differences becoming more apparent at the age of 14 years onwards, as a result of the increased leg length and muscle volume in males (Temfemo et al., 2009).

A greater take-off velocity and height of the Counter Movement Jump (CMJ) will result in greater stability of landing, particularly when combined with longitudinal, i.e., twisting rotations (Mkaouer et al., 2012). Few types of jumps were compared among USA Junior National Team male gymnasts. They showed better performances in counter movement jumps relative to static jumps, but performances were unexpectedly poorer in the drop jumps. Despite using rebound-type jumps in tumbling and vaulting with both upper and lower extremities, the drop jumps did not appear to capture the athletes' stretch-shortening cycle skill or may reflect poor stretch-shortening cycle skill (Suchomel et al., 2016). Research in youth soccer players found that training drop jumps or countermovement jumps twice a week with two different training methods that were assigned for 6 weeks improved both power and agility (K. Thomas et al., 2009). Swedish TeamGym discovered both sex and age-group differences for CMJ where males jumped 34% higher than females. Jumping height was lower for juniors compared to senior gymnasts for both genders (Höög & Andersson, 2021).

Anaerobic power was measured in 11-year-old children from gymnastics, swimming, team handball and tennis. Gymnasts had the most explosive muscular performance and were also more explosive jumpers compared to children from the other sports (Bencke et al., 2002).

Fitness tests from three levels of national teams of U.S. Gymnastics were assessed using field tests in 1990, measuring flexibility and strength/power. The tests included handstand pushups, vertical jumps, 20m dashes, splits, leg lifts and all strength/power tests when calculated relative to body mass. The absolute values tended to differentiate junior B athletes from junior A and senior athletes, with junior A and senior not differing. This indicated that the junior levels performed generally better than the senior athletes. This study supports the importance of the strength/power to body mass ratios and that even the highest levels of gymnastics performance can be differentiated by physical performance (W. Sands et al., 1991).

Enhancing the aerobic endurance of gymnasts has always been a dilemma among coaches and scientists involved in gymnastics. Coaches still believe that long aerobic endurance sessions assist weight control and enhance recovery, especially in female gymnasts. There is evidence that aerobic endurance training may interfere with power. The literature provides evidence that anaerobic types of training can enhance aerobic components effectively such as interval training or circuit training. This study gives evidence that strength training is one of the most important factors in shaping the male gymnast's physiological profile. It gives indexes to strength and gymnastics coaches in shaping the physiology of these athletes beyond a performance perspective (Jemni et al., 2006).

With explosive sports requiring rapid maximal muscular force production, such appropriate manipulation of the stretch shortening cycle to increase efficiency has had a consequential positive effect on sports performance (Chimera et al., 2004). Sport-specific plyometric training effectively stimulates muscle spindles, which involves agonist muscle preloading and elastic energy storage. Through the manipulation of intensity and volume, the force-generating capacity of the stretch-shortening cycle to initiate forceful muscular contractions can be altered (Bishop et al., 2009). Plyometric training has had a positive outcome to force production (Malisoux et al., 2006), muscular power (K. Thomas et al., 2009), running velocity (Kotzamanidis, 2006) and running economy (Kerdok et al., 2002).

1.5.4 Coordination and balance

A crucial point in the study of learning is understanding the determining factors in the modes of coordination. Most skill acquisition theories consider learning as a transition process, from an initial pattern of response to more effective and/or efficient patterns. In other terms, motor learning does not occur `de novo', but rather against the backdrop of pre-existing capacities. The central problem, for motor learning practitioners such as teachers or coaches, is to help novices overcome their initial response modes, and guide them and/or allow them to discover the to-be-learned pattern (Walter & Swinnen, 1994).

The expertise paradigm provides an interesting method to identify the effects of both motor learning and organismic properties on coordination dynamics. Expertise in a given sport is often defined in terms of a specific motor coordination, which may in turn modify the entire set of intrinsic organismic properties (Oullier et al., 2002). Research that analyzed the coordination exhibited by novices in their first trials in a complex whole-body task, which was to swing under parallel bars, showed that the novices improved their performance during the eight first sessions of practice. Even if they did not measure up to the experts as to amplitude, one can maintain that they reached their goal. This experiment shows that the behavior of beginners, in a novel task, is highly constrained by the intrinsic dynamics of the system, and that overcoming these spontaneous tendencies remains difficult (Delignières et al., 1998).

Previous studies have presented the similarities between the handstand and erect posture, however, the joints involved in the control of these postures are different (Gautier et al., 2009; Williams et al., 2016). Although the coordination in erect posture is usually described in terms of the relative phase between the ankles and hips, (Oullier et al., 2005) three main joints seem to be used in the handstand: wrists, shoulders, and hips (Gautier et al., 2007, 2009; Kerwin & Trewartha, 2001).

One of the most common movements in dance elements in gymnastics is a turn around a vertical axis with one supporting foot on the floor—a pirouette. If the pirouette is not performed with the body in balance, it is not considered successful. The results of this study demonstrate the difficulty of achieving many rotations when the body is held rigidly, whereas dancers may have success in consistently performing more pirouettes if they are taught strategies for regaining balance while turning (Lott & Laws, 2012). Few studies have investigated how balance is maintained while the body rotates in an upright posture. In the basic definition of balance, the body's center of mass (CoM) lies along a vertical line over the base of support (BoS); therefore, balance can be regained by moving the position of the CoM or the BoS. In a ballet pirouette, extreme movement of the BoS is aesthetically unacceptable; however, subtler BoS translations may be a viable strategy for balance maintenance. Dancers are often taught to perform successful pirouettes by beginning the movement on balance and then keeping the body in that configuration, as opposed to correcting for an imbalance with small adjustments during the turn. But on the contrary these results suggest that dancers should be encouraged to make adjustments that could lead to subtle BoS translations during rotations (Lott, 2019).

1.5.5 Flexibility

Stretching, following submaximal aerobic activity, has been shown to increase the range of motion further. This study suggests that a duration of 30 seconds is an adequate time of stretching to enhance the hamstring muscles’ flexibility. Given that no increase in flexibility of the hamstring muscles occurred by increasing the duration of stretching from 30 to 60 seconds, the use of the longer duration of stretching for an acute effect must be questioned (Bandy & Irion, 1994). According to the literature, dynamic stretches and activities will have no detrimental effect or augment performance. Longer durations of dynamic stretching and activity seem to provide a positive response to the neuromuscular system enhancing performance.

Previous studies reported that static stretching might temporarily decrease the ability of the stretched muscles to generate power output (Behm et al., 2001). A study on netball players that compared static stretching and dynamic warm-up found no difference in performance. It was suggested that if static stretching is to be included in the warm-up period, it is recommended that a period of high-intensity sport-specific skills-based activity is included before the on-court/field performance (Taylor et al., 2009).

The duration and intensity of the static stretching exercises seem to play a critical role in these impairments, with long-lasting, intense stretching exhibiting a more significant decrease in subsequent power generating ability (Behm & Chaouachi, 2011).

As static stretching can still increase range of motion (ROM), it still plays a vital role in health-related benefits associated with flexibility and particular sports or activities that necessitate a tremendous increase in static ROM relative to the flexibility of the athlete or patient. However, static stretching should typically not be pursued before strength, high speed, explosive or reactive activities. All individuals should include static stretching in their overall fitness and wellness activities for the health and functional benefits associated with increased ROM and musculotendinous compliance. However, a separate static stretch training workout time or during post-exercise cool-down should be planned independently of other training workouts or competitions to achieve a more permanent change in flexibility for health or performance (Behm & Chaouachi, 2011).

A study that examined the effects of baseline flexibility and vertical jump ability on straight leg raise range of motion (ROM) and counter movement jump performance (CMJ) focused on stretching and potentiating exercises in elite gymnasts in the Greek national team. In particular, the effects of two different stretching durations (15 sec and 30 sec) were studied in combination with two different volumes of conditioning tuck jumps, aiming to enhance CMJ performance at the end of the warm-up. One main finding of the study was that the initial level of lower limb flexibility and vertical jump ability did not alter the responses of elite gymnasts to the two warm-up conditions. The second main finding was that CMJ performance in the long warm-up condition increased considerably by 4.6%, despite a relatively significant increase in flexibility by 5.9%. The study results indicated that the long stretching duration (30 sec) increased flexibility without impairing jumping performance immediately after stretching. This may be due to the fact that elite-level gymnasts were accustomed to stretching of extended duration (>2min). Thus static stretching durations of 15 and 30 secs were probably too short of having any effect on CMJ performance (Donti et al., 2014).

One recent study by Chaouachi (2010), was to investigate the effects of static and dynamic stretching alone and in combination on subsequent agility, sprinting. Jump performance showed that static stretching to the point of discomfort did not affect sprint and jumping performance in elite athletes and attributed it to their high training status. Based on these findings and the literature, trained individuals who wish to implement static stretching should include an adequate warm-up and dynamic sport-specific activities with at least five or more minutes of recovery before their sport activity. It may be argued that the elite level gymnasts did not show an impairment of CMJ performance after stretching because their training involves a large volume of stretching exercises of similar characteristics (Donti et al., 2014).

Flexibility is perhaps the single most significant discriminator of gymnastics from other sports. The extreme ranges of motion achieved by gymnasts require long periods of training, often occupying more than a decade (W. A. Sands et al., 2016).

1.5.6 Speed

Speed is the ability to move from one point to another in the shortest time possible. It is influenced by one's reaction time, or the amount of time elapsed from the signal "go" to the first movement of the body and then the time elapsed from the initial movement to completion of the activity. Reaction time is generally considered to be innate, but movement time may be improved with practice (Gallahue & Donnelly, 2007, p. 91).

Both boys and girls show similar sprint speeds during the first decade of life (Malina et al., 2004). A period of accelerated adaptation is suggested occurring between the ages of 5 and 9 years in both sexes (W. A. Sands et al., 2002). From the age of 12 years, the progression of speed development is dramatically reduced in females compared with males.

The second period of accelerated adaptation has been reported to occur around when girls are around 12 years of age and between 12 and 15 years in boys (Lloyd et al., 2011).

Research on speed training found that the magnitude of speed gains was similar for pre-adolescent soccer players involved in coordination training and traditional straight-line sprint training without the ball. Still, the coordination training group was better at running with the ball. This finding supports the role of coordination and neural control in speed development before maturation, although whether these factors are more trainable during pre-adolescence is not known (Venturelli et al., 2008).

Longitudinal changes in height, weight, and physical performance studied in Flemish male youth soccer players reported that sprint speed in youth footballers showed the most significant gains around the time of peak height velocity, suggesting a combined training and maturational effect. However, the longitudinal data presented by (Philippaerts et al., 2006) showed a decline in sprint performance in the 12 months preceding peak height velocity. Any subsequent gains may have reflected a correction of the previously impaired performance. Improvements in speed around peak height velocity may also be related to increased lower limb length, reflecting an entity that is not trainable. Rapid periods of physical growth may disrupt motor coordination in some individuals, a phenomenon known as “adolescent awkwardness” (Beunen & Malina, 1988; Philippaerts et al., 2006).

Vault is one of the apparatus for all disciplines in gymnastics. A Turkish study (2021) investigated the relationship of an approach run in terms of age, gender, and physiological factors. As the approach run velocity increases, vaulting performance is affected positively. The study showed that while speed tests significantly correlated with the approach run in male gymnasts, there was no correlation for females. In gymnastics, the approach run to the vault is not expected to be performed at a maximum speed. An optimal approach run will become the basis for the next element. The velocity loss during the other vault phases may help gymnasts perform the element to a required quality (Bayraktar et al., 2021). However, in real-life settings, even highly experienced TeamGym gymnasts may not benefit entirely from maximal running velocity during the run-up. The gymnast must overcome the reactive force during the time of contact with the trampette before take-off. If the achieved approach velocity is too high, the gymnast may find it difficult to reach the preferred hip and knee joint angle position at the instant of eccentric-to-concentric SSC transition and at the instant of take-off, thereby not reaching the optimal vertical height of the jump. Thus, it is unlikely for TG athletes to use their maximal sprint capacity (Hansen et al., 2019). In contrast, in competitive team sports such as football and team handball, the ability to repeat maximal sprints during a match generally is considered an essential factor (Bangsbo et al., 2006). When the correlation between anaerobic power and approach run was examined, high correlations were found for female and male gymnasts (Malina et al., 2004). In a Swedish TeamGym study, Högg & Andersson (2021) found a difference in running speed for males and females, where females ran 4% faster than males, which was unexpected. Males show a difference in running speed with age, with male seniors performing better than juniors.

1.6 Psychological factors

Many sports psychologists have turned to inventories that measure sport-related behaviors rather than any underlying personality dimensions that might be linked to those behaviors. There is considerable interest in instruments targeting psychological skills and strategies in sport. They are likely to differentiate athletes and provide evidence regarding the efficacy of psychological skills training programs (L. Hardy et al., 2010).

Successful athletes have reported greater self-confidence, lower anxiety levels, more task-oriented thoughts, and use more self-talk and positive imagery than less successful athletes. This was reported in several studies (Gould et al., 1993; Neil et al., 2006).

1.6.1 Psychological skills

According to Weinberg & Gould (2019), psychological skills help sportspersons enhance athletic performance. The basic psychological skills include imagery, goal setting, relaxation, self-talk, emotional control, and self-confidence. Athletes performing at international and national standards reported more psychological skills and strategies usage and less negative thinking than club/recreational athletes. Automaticity was an exception. Older athletes reported more automaticity in executing skills than younger athletes (P. R. Thomas et al., 1999). However, it is not clear why male athletes performing at international and national standards reported lower automaticity levels in competition than less-skilled male athletes. There was no clear pattern of differences in female athletes (P. R. Thomas et al., 1999) examining Olympic champions' psychological characteristics. These elite athletes were high on goal setting, activation, relaxation, emotional control in competition, goal setting, and attentional control at practice (Gould et al., 2002).

Frey et al. (2003) urged sport psychology consultants to make coaches aware of the relationship between mental skill use in practice and success in competition so that athletes would use mental skills when practicing their physical skills, thereby enhancing the quality of practice.

Test of Performance Strategies (TOPS) is a self-report instrument designed to measure an athlete's psychological skills and strategies during competition and practice among adolescent athletes. The TOPS was designed to measure a comprehensive range of psychological skills and techniques and their strategic use by athletes in competition and at practice. Subscales were developed targeting eight of the most salient psychological skills and processes to underlie successful athletic performance. These skills are goal setting, relaxation, activation, imagery, self-talk, attentional control, emotional control, and automaticity. All these skills and strategies are measured in practice. Still, due to exploratory factor analyses by (P. R. Thomas et al., 1999), negative thinking rather than attentional control is measured in competition (L. Hardy et al., 2010).

Before the London Olympic Games, the psychological skills of elite artistic female gymnasts' national teams of Hungary and Great Britain were compared. The application of TOPS was used for measurement. Hungarian gymnasts scored higher in self-talk and the British in using imagery as a psychological skill (Kalmár et al., 2014).

Imagery can improve sports performance and should be an essential advantage, according to Omar-fauzee et al. (2009). Imagery is an indispensable part of coping strategy in peak performance, according to other authors (Gregg et al., 2007). Self-talk is an unambiguously important psychological skill, positive talk that can lead to victory, according to Raalte et al. (1995). In investigating self-talk and affective states, a correlation was found between positive and negative talk and motivated and unmotivated states (J. Hardy et al., 2001), which proves that negative self-talk decreases motivation. On the other hand, negative self-talk may improve achievement/performance as well, depending on how the individual interprets it. It is thought that negative self-talk and negative thinking go hand in hand and increase anxiety (Kalmár et al., 2014).

Measures of competitive anxiety, self-confidence, and psychological skills were made on elite vs. non-elite Rugby players. The elite group reported more facilitative interpretations of competitive anxiety symptoms, higher levels of self-confidence, lower relaxation usage, and greater imagery and self-talk use than their non-elite counterparts. The findings suggest that non-elite performers primarily use relaxation strategies to reduce anxiety intensity. In contrast, elite athletes appear to maintain intensity levels and adopt a combination of skills to interpret symptoms as facilitative to performance (Neil et al., 2006).

In research on Team handball players, psychological skills, mental toughness, and anxiety were measured according to age and gender. The results showed only slight differences in age in psychological skills, mental toughness, and no difference in anxiety. Nor were there differences by sex, with just men scoring lower on anxiety than women (Kristjánsdóttir et al., 2018).

Researchers such as Lane (2004) have suggested that it might be more important to investigate the skills among young athletes and integrate psychological skills training to their programs. The use of TOPS has shown to be more beneficial in older athletic populations from 16-20 years than younger population from 12 - 15 years of age (Katsikas et al., 2011), that possibly indicates that the younger participants did not understand the questions' meaning (Lane et al., 2004). Psychological Skill Training for elite junior gymnasts executed in France was very successful. The five-step intervention consisted of relaxation, self-talk, goal setting, focusing and visualization. They had a 30-minute psychology training per week. Performance scores were obtained using scores and rankings during two consecutive competitive seasons, for ten months. In three events out of four (bars, beam, floor), the ten gymnasts progressed 5% more than eleven other gymnasts who did not follow this program (Fournier et al., 2005).

1.6.2 Mental toughness

Mental toughness is often referred to as one of the most important psychological attributes underpinning athletes' success. In a study of quantitative literature, the findings support the commonly held belief that mentally tougher athletes tend to be more successful (Cowden, 2017).

Researchers have been unable to agree on a common definition of mental toughness. Still, the different definitions usually refer to the sportsperson's ability to concentrate, rebound from failure, cope with pressure, and face adversity, as well as mental resilience, commitment, and confidence (Bull et al., 2005). There has been an increased awareness and understanding of the psychological factors involved in athletic performance in recent years. Within this, mental toughness is now acknowledged as one of the essential attributes in achieving athletic success (Bull et al., 2005; Connaughton et al., 2008; Thelwell et al., 2010). This important factor can be measured with the Sport Mental Toughness Questionnaire (SMTQ) (Sheard et al., 2009).

The relationship between pre-competition mood state factors was investigated in Hungarian artistic gymnasts by gender, age, and their national ranking one day before their main competition of the year. Consistent with theoretical predictions, results confirmed that several pre-competition mood states differed by age, with both juniors and seniors having a higher level of anger than the normal value. Also, seniors demonstrated higher tension. However, only anger showed significant differences by gender, with male gymnasts demonstrating higher levels of anger than female gymnasts and with elite gymnasts registering higher levels of anger compared with recreational gymnasts (Boldizsár et al., 2016).

In a study by Thelwll (2010), five female gymnasts from Great Britain and five from the United States participated. Three of the ten participants were medal winners at major international events, and nine of the ten participants were still competing at an international level. The study was to examine how mental toughness is developed from a sport-specific approach. In support of findings from previous research, it suggested mental toughness development to be a complex phenomenon.

It was reported that when mental toughness had been developed, these three perceived underlying mechanisms were required to maintain it: a support network that included sporting and non-sporting personnel, a desire and motivation to succeed that was insatiable and internalized, and effective use of basic and advanced psychological skills (Connaughton et al., 2008).

1.6.3 Anxiety

Coping with pressure and controlling anxiety both before and during competition is an essential psychological skill for athletes. A high level of competitive anxiety, both cognitive and somatic, can considerably impact performance (Wilson et al., 2009). An Italian study was performed on TeamGym, males and females measuring psychological and physiological responses to stress during competition. Those findings provided evidence that the psycho-physiological stress response before and during competition can affect performance outcomes, especially in technical sports (De Pero R et al., 2015). According to Musculus & Lobinger (2018), anxiety levels influence performance.

Higher levels of trait anxiety were found in 10–12-year-old competitive gymnasts compared to recreational gymnasts of the same age. Socially prescribed perfectionism for gymnastic competition was observed in a study comparing self-esteem and trait anxiety. Gymnasts from the competitive group reported significantly higher levels of trait anxiety than the recreational group (Donti et al., 2012). An interesting case study was made where six male and female junior gymnasts in Mexico were analyzed for psychophysiological responses to acute psychological stress during visualization of competition, under the influence of pressure for perfection exerted by parents and pressure for perfection exercised by the coach. The results showed a physiological and anxiety response to socially prescribed perfectionism for gymnastic competition (Pineda-Espejel et al., 2020).

Females have reported higher anxiety levels than males in a study on athletes’ approach-avoidance achievement goals as mediators between their implicit beliefs of sports ability and sport-related cognitive anxiety. This may be due to their different performance-approach goals or their desire to outperform others (Stenling et al., 2014). Also, some research in team sports has shown lower levels of anxiety in male athletes than female. These findings seem to suggest that there is a need for specific programs targeted at females to allow them to cope appropriately with high levels of anxiety (Kristjánsdóttir et al., 2018; Neil et al., 2006).

In gymnastics, it is not uncommon for athletes to face fear. In a study by (2015), the fear felt by gymnasts in training was analyzed to detect subjective perceptions about the causes of fear and the strategies utilized to control it. The subjects were nine to ten-year-old girls in Brazil. They detected four primal causes of fear: fear of injury, error, apparatus, and coach. Regarding strategies for controlling the fear, they detected seven units: social support from friends and family, instructional support, attention and concentration, positive thinking and self-confidence, mental practice, and relaxation techniques (Duarte et al., 2015).

A study examined female gymnasts' fear of injury, their sources of self-efficacy, and the psychological strategies used to overcome their fears. The participants were juniors who had all taken part in competitive gymnastics and had experienced some type of injury during their careers. The results indicated that gymnasts were most fearful of injuries because of the difficulty in returning from an injury and being unable to participate in training and competitions while injured. Some examples of psychological strategies used to overcome their fear of injury were mental preparation, e.g., imagery, relaxation, just "going for a skill", and the coaches's influence (Chase et al., 2005).

The sports physiotherapist must be aware of stress being a predisposing factor to an injury during the rehabilitation process. The psychological role in injuries was documented in subjects who were requested to measure life stress, competitive anxiety, self-esteem, and locus of control. It was found that life stress was a predictor of injury for the overall sample and for the non-elite gymnasts. For the elite gymnasts, a more internal locus of control significantly predicted injury. The findings indicate the importance of the sports physiotherapist's awareness of stress both as a predisposing factor to injury and as a variable that should be considered during the rehabilitation process (G. Kolt, 2004).

In a study by Kolt & Kirkby's (1996) there was a link between life stress and injury in gymnastics. These findings interested physiotherapists, because for their effective practice, it is crucial to be aware of the causative factors of sports injuries, not only from a physical viewpoint but also from psychological factors. The physiotherapist should be aware of the association between life stress and injury and consider this link when establishing causes of injury and approaches to rehabilitation. It could be that teaching injured sportspeople techniques to cope with life stress reduces the risk of further injury.

1.6.4 Coaching culture

The training environment in Artistic gymnastics has derived from the military roots and strong Soviet influence on athletes's sports training since the 1970s (Arkaev & Suchilin, 2004). Still, some misleading and traditional practices persist in gymnastics, such as abusive methods for weight control, high training overload, inadequate rest and recovery (Caine et al., 2001; G. Kerr et al., 2006; Stewart et al., 2017). In Women's Artistic Gymnastics (WAG), athletes can be coach-dependent, become submissive, and this scenario may reflect subordination, harassment, and abuse. It has been pointed out that the sociocultural context of high-performance training gymnastics has a hierarchy. The coaches have unilateral autonomy, and the gymnasts must follow them without arguing (Santos Oliveira, 2016).

Oliveira (2017) points out that in WAG, the proximity between coaches and gymnasts is accentuated, as intense body contact induces dependency, confidence, and surveillance. This contact makes coaches refer to gymnasts as "their's," that is, as a precious property, while gymnasts put their own lives in the hands of coaches. Both gymnasts and coaches seem to be aware that there is an interdependence to achieve success in sport.

In a Brazilian recherch by Costa (2020), the relationship between coach and gymnast was analyzed. They were suggesting that female gymnasts were the "puppets" of their coaches. The conclusion was that gymnasts are not puppets without their own opinion. Still, they develop a "gymnast habitus" legitimized by symbolic violence in the power relationship with the coach, aiming to maintain the culture of the WAG's field.

Athletes and coaches agree that the gymnast's development depends on the coach, and the coach's reputation depends on the athlete. Gymnasts and coaches have a tacit agreement that athletes should follow the coaches' guidelines unquestioningly. Coercive acts, lack of dialogue, constant vigilance, surveillance, and demands permeate this relationship scarcely discussed in specialized literature (Oliveira et al., 2017). As previously mentioned gymnasts show an anxious response to parents and coaches perfectionism (Pineda-Espejel et al., 2020).

Changes in this scenario will require a lot of effort and time because the habitus does not undo itself. It can transform in the long run through long-lasting dispositions. In this context, gymnasts are at a disadvantage in relation to the coaches and the system, including parents, media, sponsors, and federations. If these structures would not demand early outcomes, the athletes could be adults when they reach the sport's high-performance level. Thus, they would decide by themselves whether they want to continue in this "game of domination" with it's consequences (Costa et al., 2020). Moreover, Oliveira et al. (2017)

found that athletes learn to be submissive to coaches, so independent gymnasts could be seen as problematic and challenging to work with.

The purpose of Costa et al., study was to arouse concerns and reflections that could trigger further research and, perhaps, changes in the WAG's socio-cultural context. The coaches need to learn and recognize their role as educators and the limits of abuse, charge, discipline, and punishment. Then, they would recognize or exclude undesirable attitudes, clarify their training methods and stimulate communication with parents and children (2020).

Since 2018, change in the culture has led to many countries having professionals working with artistic gymnastics sentenced or banned from the sport (Costa et al., 2020). Faced with the abuses mentioned earlier, the International Gymnastics Federation (FIG) has implemented measures to prevent nonaccidental violence, harassment, and abuse (FIG, 2018). Each national federation shall adopt and enforce such policies to protect their athletes from identifying and eradicating unacceptable practices through these safeguarding procedures.

Reflecting and understanding the context as a whole, from both the gymnast's and the coach's point of view, is essential to think about how the transformation of the habits of the gymnasts could favor more positive experiences in WAG (Costa et al., 2020). Despite those cases, recent studies analyzed the phenomenon of career extension in WAG and have identified that with the advent of older high-performance gymnasts, the coach-athlete relationship could emphasize gymnasts well being but still achieve actual results (Barker-Ruchti & Schubring, 2016; R. Kerr et al., 2018; Z. Y. Kerr et al., 2015).

The relationship between perceptions of coaches' interpersonal styles, athlete's goal orientations, mental toughness, and future intention of sports practice was tested in Spanish athletes. The data support and confirm previous research, indicating that coaches play an important role in shaping the cognitions and experiences of athletes. So coaching education programs must help coaches increase the use of autonomy-supportive behaviors and decrease the use of controlling behaviors if we want to promote positive athlete outcomes (Álvarez et al., 2018).

1.7 Injuries in gymnastics

Although gymnastics is an old sport and has used the same apparatus since 1950, it has changed a lot during those years. The number of participants has increased and developments in sports science and biomechanics has added to the competitiveness of the sport, which in turn has led to higher injury risk factors (G. S. Kolt & Kirkby, 1999). All disciplines of gymnastics need high technical skills and physical fitness to perform skills of acrobatic and gymnastic elements (Höög & Andersson, 2021).

The nature of gymnastics requires high weight-bearing for the upper extremities. These high-impact loads put enormous strain on the arms and wrists that are not well adapted for these types of forces. This can lead to overuse or stress injuries (Carter & Aldridge, 1988). Growth plates in children and adolescents are less resistant to shear and tension forces and maybe 2-5 times weaker than surrounding fibrous tissue (Larson & McMahan, 1966).

(Harringe, 2004) reported a significantly higher proportion of overuse injuries in teamgym gymnasts compared with other disciplines of gymnasts, and the lower extremity was found to be the most common region for injuries.

A study by Harringe (2007) on injury incidence in elite TeamGym gymnasts, no gender differences were found. Sixty-two percent of the injuries were located in the lower extremity, 28.5% to the back, and 9.5% to the upper extremity. The most common injury was an ankle sprain, and the most frequent mechanisms leading to injuries were joint compression and joint rotation. The majority of the injuries occurred in the landing phase of the gymnastics skills, and 50% of the injuries were reported at the end of a training session. Lund & Myklebust (2011) stated that 84% of injuries occurred in competition and during the landing phase and that gender was irrelevant. This data agrees with numbers from artistic gymnastics, where most injuries are due to impact in landing or striking apparatus or surface (W. A. Sands, 2000). Negative state of mood, such as stress or fear, has been stated to increase the risk of injuries (Harringe et al., 2007).

Injuries were recorded for WAG and MAG in relation to the event and exercise phase. The incidence of injury to the ankle and knee was significantly higher in the floor exercise, especially during the landing phase (Kirialanis, P et al., 2003).

In TeamGym a higher injury rate was observed in competition than during the pre-competition warm-up. Eighty-four percent of the injuries occurred in the landing phase of the gymnastic skill. No differences were observed in males and females and ankle injuries were the most common. A high number of gymnasts competed with overuse or acute injuries that had not recovered fully (Lund & Myklebust, 2011a).

1.7.1 Injury prevention

Most evidence for preventing injuries in gymnastics is based on information on physical fitness including strength, flexibility, and conditioning from other sports (Daly et al., 2001). Reduced lower body muscle power led to more severe injuries among female contemporary dancers when investigating the effects of physical fitness levels in few professional dancers (Angioi et al., 2009).

According to a systematic review, both overuse and acute injuries could be reduced with preventive programs. Best results to reducing injuries come from physical activity-based programs that include combinations of different exercises than proprioception training only. Strength exercises should consist of concentric/eccentric training of *hamstrings*, *quadriceps*, *gastrocnemius*, and *soleus*. Stretching exercises do not add any protective effect against sports injuries (Silva, Priscilla Viana et al., 2018).

Many injuries in adolescents are during school and low league training, therefore coaches need further knowledge of individual risk patterns of different sports. It is important to provide preventive medical check-ups to monitor the physical fitness needs for each sport (Habelt et al., 2011).

It is crucial to ensure correct progression and overload when building plyometric programs for youth and junior athletes to avoid injury. The program should be developed low to moderate in intensity and focus on the technical quality of the exercises that should be sport-specific in relation to increased power production. Overload should be increased progressively in both intensity and volume. Higher overload intensity can be controlled with different exercises, increased number of repetitions and sets, and elevated jumping heights (Marina & Jemni, 2014). It is essential to ensure that the plyometric training or power programs provide appropriate recovery periods, 24–48 hours, to enable adaptations for the youth gymnasts and minimize the risk of injury (Hall et al., 2016).

According to Arnason (2004) rehabilitation and physical fitness is important injury prevention, thus previous injuries are the biggest risk factor for recurrent injuries. A prevention warm-up program called The 11+ consisting of running exercises, strength, balance and jumping exercises and finally speed running with some football-specific movements has been helpful prevention program for young football players if performed at least twice a week for 20 minutes (Rahnama, 2012).

Neuromuscular training prevention programs have become popular among many sports. The program has shown at least 35 % less injuries in team sports when including strength, balance, aerobic, and agility training (Emery & Pasanen, 2019).

Physiotherapists involved in gymnastics in Australia recommended injury prevention essentials for artistic gymnastics based on life experiences not yet supported by scientific evidence. Their input may be necessary for all gymnastics coaches to recognize and be used to guide future research investigating injuries in gymnastics (Cossens, 2012).

2 Current Study

The Manuscript

A manuscript of the current study will be submitted for publication on the following pages. It includes the introduction, methods, results, discussion, conclusion, limitations, and references. The reference page for the entire thesis follows immediately after the manuscript.

2.1 Abstract

The objectives of the present study were: (1) to evaluate the difference in anthropometry, body composition, and physical fitness concerning age, gender, and discipline; (2) to evaluate the difference in psychological skills in terms of age, gender, and discipline; and (3) to identify the impact that the competition period had on physical measurements of elite gymnasts in Iceland. Methods: Eighty-six gymnasts from three gymnastics disciplines; Women’s artistic gymnastics, Men’s artistic gymnastics and TeamGym, participated in the study. The physical tests were: The Men‘s Gymnastics Functional Measurement Tool and The Gymnastics Functional Measurement Tool. Three questionnaires were on offer: the Test of Performance Strategies Questionnaire, the Sport Mental Toughness Questionnaire, and the Sport Anxiety Scale–2 Questionnaire. The Independent samples t-test was used to compare groups and the Paired samples t-test to compare pre-and post-measurements. Physical results: Seniors scored higher than juniors in all except push-ups. Males had more strength than females, who had more flexibility. Artistic gymnasts had more hanging strength and flexibility than TeamGym, who had more grip strength and speed. Psychological results: seniors had more activation than juniors, who had more imagery. Females used more self-talk in practice than men and TeamGym showed more emotional control in practice than Artistic. Male showed more control than females, who showed more worry and concentration disruption. Juniors show more concentration disruption than seniors. Post-competition period flexibility and balance was less than pre-competition. Conclusion: Maintaining physical abilities during competition period and training psychological skills might benefit elite Icelandic gymnasts.

2.2 Introduction

Gymnastics is one of the oldest sports in the world, with many different disciplines. A gymnast requires years of training before routines that suffice in even the lowest levels of competition. Since 1997, age regulations have changed and gymnasts must be older to compete in major events. Juniors are judged under the same rules as the seniors and often exhibit the same difficulty in their routines (Sands et al., 2002). The age of WAG has increased incrementally (Mujanović et al., 2020; Myrian et al., 2019). Anthropometric measurements from the European Games in 2015 show that artistic gymnasts are shorter and lighter than athletes from other sports (Silva et al., 2020). Their body composition was unique and similar to those of competitive bodybuilders and professional ballet dancers (Vercruyssen, 1984). TeamGym gymnasts were considerably taller and heavier than artistic gymnasts, which was considered beneficial because of the difference in the equipment with more rebounding for a gymnast with greater body mass (Hansen et al., 2019).

The literature has shown that children can undertake strength training as long as those programs are designed and supervised by professionals (Ford et al., 2011). Programs for children need to combine successfully with employed training methods and a scientific basis. An athlete's peak height velocity is monitored to maximize athletic potential (Balyi & Hamilton, 2004). Gymnastics is an early specialization sport where complex skills need to be learned before maturation to be fully mastered (Balyi et al., 2013). According to Gallahue & Donnelly (2007), the whole period of childhood is considered a sensitive period for learning and mastering fundamental skills. For athletic development, it is essential to identify periods where sensitivity to training adaptations is possible in conjunction with correct training stimulus (Viru et al., 1999).

Physical demands for gymnastics are extensive, with primary emphasis on strength combined with incredible flexibility and power relative to body weight (Arkaev & Suchilin, 2004; Ford et al., 2011). Gymnasts need explosive power in the lower limb musculature to perform a multitude of required jumping skills while maintaining body control (Jemni et al., 2006; Marina & Jemni, 2014). Evidence suggests that speed development is dependent on coordination and neural control obtained around peak height velocity before maturation. It is unknown if speed is more trainable during preadolescence or influenced by the combination of training and maturation (Philippaerts et al., 2006; Venturelli et al., 2008). Before the age of 14, strength increases equally for both males and females, but males show a rapid increase compared to females. Like all fitness components, individual timing of growth and maturation is more important than chronological age (Round et al., 1999). For TeamGym gymnasts, lower body strength was considered more important than upper body strength (Höög & Andersson, 2021). Artistic gymnastics is highly weight-bearing for the upper extremities with high-impact loads on vulnerable wrists (Carter & Aldridge, 1988). Gymnasts are amongst the strongest Olympic athletes when relative strength is measured in relation to body weight (Hansen et al., 2019). Physical fitness tests have shown that even the best gymnast can be differentiated by physical strength/power to body mass ratios performance (W. Sands et al., 1991). According to Sands (2016) gymnasts differentiate themselves from other sports with flexibility and a high range of motion achieved by often decades of training.

Psychological skills and behaviors differentiate athletes more than any underlying personality dimensions (L. Hardy et al., 2010). Studies have shown greater self-confidence, more task-oriented thoughts, and lower anxiety levels, using positive imagery and self-talk in successful athletes (Gould et al., 1993; Neil et al., 2006). Older athletes reported more automaticity in executing skills than younger athletes. Males performing at international and national standards reported lower automaticity levels in competition than less-skilled male athletes. However, female athletes showed no differences (P. R. Thomas et al., 1999). Elite junior WAG gymnasts increased their score on three events by 5% more than the control group after training psychological skills 30 minutes a week for ten months (Fournier et al., 2005). Handball players showed a slight age difference when comparing psychological skills and mental toughness but no difference in anxiety. No difference was found between gender, except females scoring higher on anxiety than males (Kristjánsdóttir et al., 2018). Mental toughness is considered one of the essential attributes in achieving athletic success, and it is vital for the athlete to cope with pressure, adversity and failure, as well as displaying resilience, confidence, concentration and commitment (Bull et al., 2005). Stress can induce a psycho-physiological response and affect competition in technical sports (De Pero R et al., 2015). Both male and female junior gymnasts showed physiological and anxiety responses to socially prescribed perfectionism during the visualization of competition (Pineda-Espejel et al., 2020). Females report higher anxiety levels than males for approach-avoidance achievement goals (Stenling et al., 2014).

Physical fitness is crucial in preventing both overuse and acute injuries. Best results for reducing injuries come from varied physical activity-based programs (Silva, Priscilla

Viana et al., 2018). Reduced lower body muscle power led to more severe injuries among female contemporary dancers when investigating the effects of physical fitness levels (Angioi et al., 2009). Preventive medical check-ups are necessary to monitor each sport's physical fitness needs (Habelt et al., 2011). Psychological factors can predict injury in gymnastics and should be considered during the rehabilitation process (G. Kolt, 2004; G. Kolt & Kirkby, 1996). Training physical fitness and psychological skills can increase success in competition and improve mental health and prevent gymnasts from injuries.

In this context, the objectives of the present study were: (1) to evaluate the difference in anthropometry, body composition, and physical fitness concerning age, gender and discipline; (2) to evaluate the difference in psychological skills in terms of age, gender and discipline; and (3) to identify the impact that the competition period had on physical measurements and psychological skills of elite gymnasts in Iceland.

2.3 Methods

2.3.1 Type of study

The study is both a cross-sectional study and longitudinal study of anthropometry, body composition, physical fitness and psychological elements of elite gymnasts in Iceland. The independent variables were age, gender and disciplines. The dependent variables were anthropometry, body composition, physical fitness and psychological tests, and the time of the competitive period.

2.3.2 Participants

A hundred and eight national team gymnasts selected in the 2020 season from three different disciplines were recruited for one or both measurements. A total of 86 gymnasts participated in the physical test or 79.6%. A total of 69 gymnasts participated in the psychological test or 63.9%. Age limits were different for all disciplines, MAG juniors (14-17) and seniors (18 and above), TG juniors (13-17) and seniors (18 and above) and WAG juniors (13-15) and seniors (16 and above). The participants were informed that their participation was voluntary. They wore light clothes and no shoes during the measurement.

Table 1

Summary of participants.

Discipline	Artistic Male	Artistic Female	TeamGym Male	TeamGym Female	Total
Junior	4	21	9	21	55
Senior	9	6	9	7	31
Male	13		18		31
Female		27		28	54

2.3.3 Evaluations/instruments

The sport-specific physical test was based on the Men‘s Gymnastics Functional Measurement Tool (MGFMT) (Sleeper et al., 2016) and the Gymnastics Functional Measurement Tool (GFMT) (Sleeper et al., 2012). The physical test was adapted for comparison and submitted for all disciplines. In TG, a different push-up test was used for males and females. Additionally, a few tests were done that had been previously used in Icelandic gymnastics. For the psychological tests, the participants completed three different questionnaires to analyze psychological skills, mental toughness, and anxiety in elite gymnasts in Iceland.

2.3.4 Physical measurements

Anthropometric and body composition measurements were carried out using standardized protocols and a portable stadiometer measured height and weight (Balyi & Way, 2005). Tanita was used for body composition analysis. The validity and reliability of Tanita BC418 analysis were done by Kelly & Metcalfe (2012). Measurements were recorded for the dominant side, arm length from the *acromion* to fist, from the *acromion* to finger III, and leg length from *ASIS* to *medial malleolus* (Sleeper et al., 2012, 2016).

i. Grip strength was measured for both left and right sides with a handle connected to a computer system (Venier Graphical Analysis). Gymnast was seated with the tested arm in 90° flexion and squeezed the handle for a few seconds as hard as possible without any body movement.

ii. In the rope climb test the gymnast started in a seated pike with legs together directly beneath the rope with their hands on the start line on the rope. It began when the gymnast left the floor and stopped when they touched the 15-foot (4.57 m) mark measured from the start line or could not continue climbing. Scoring was based on the gymnast’s ability to complete the climb, the amount of time to perform the climb, climbing technique, and hip and leg position maintained during the climb (Sleeper et al., 2012).

iii. A pull-up’s test. The gymnast started hanging from the standard horizontal bar with an over grip, and hips and knees flexed to 90°. A stable object was placed on the thighs at hip level to eliminate the aid of momentum in completing the pull-up. A pull-up started in the full hanging position and raising the chin to clear the bar completely, then lowered in a controlled fashion until the elbows were extended.

iv. For hanging pikes, the gymnast started the test from a dead hang, without the use of hand grips, on a standard horizontal bar. The gymnast flexed the hips with legs together and knees extended and attempted to touch the bar with the toes. The gymnasts had to show momentary dead hang between pike attempts to prevent using momentum to gain an advantage for the next pike-up.

v. The gymnast had two attempts to perform a handstand on a hard floor. Gymnasts were allowed their choice of lower extremity position while in handstand. Timing began when the gymnast reached the handstand, and timing ended when any part of the gymnast’s body touched the floor other than the hands. Timing also stopped if either of the gymnast's hands moved from their original placement. The raw test score for the handstand time was recorded with a stopwatch to the nearest one-hundredth of a second.

vi. The Y balance test was exchanged for the star excursion balance test (Sleeper et al., 2016). Both are valid tests, but the Y test is more straightforward and takes less time. The Y balance test is valid and reliable if practiced six times and measured three times, and the test number is the average of the three trials (Linek et al., 2017; Shaffer et al., 2013). Measuring tapes were attached to the floor where the best of three trials, in all three directions, were recorded for the dominant side.

vii. The gymnast's arm length was obtained before the shoulder flexibility test, from the tip of the *acromion* process to the fist. The gymnast lay prone on a firm floor with the chin and nose touching the floor for testing. Both arms were held parallel to the body with the shoulders flexed to 180°. The gymnast held a stick with an overhand grip and tips of the thumbs touching. The gymnast flexed the shoulders while maintaining the wrists neutral, elbows extended, and the nose and chin in contact with the floor. The distance from the stick to the floor was measured and recorded to the nearest ½ centimeter. The raw test score is calculated by dividing the height by the length of the athlete's arm.

viii. An over-split was performed to see if the gymnast could achieve complete contact during the splits test. The over-split involved an assistant passively flexing the lead hip while the gymnast maintained a neutral pelvis and extended knee position. The hip was flexed until the gymnast said, "stop" or until the pelvis lifted from the floor. The height from the posterior aspect of the heel to the floor was measured and recorded in centimeters. The over-split measurement was referred to as a positive (+) cm. Middle split testing involved the use of a straight line on the floor. The gymnast slid into a middle split position keeping the legs parallel to or on the line and leaned forward to place the chest on the ground to obtain the lowest split position. The distance from the *ischial tuberosity* to the floor was measured. Over-split was carried out and measured in the same manner described for the splits. The positive or negative angles calculated from the left, right, and middle were then added to give a final split score.

ix. For vertical jump, we used a jump mat to measure jump height. The gymnasts performed an Abalakov jump two times on the mat. The gymnast was allowed to freely coordinate the arms and trunk movements to reach the maximum height.

x. Two cones were placed diagonally at the corners of a 12 m x 12 m artistic gymnastics competition floor for the Agility test. The gymnast started standing, feet together in the corner in front of a cone, imitating a tumbling pass. When ready, the gymnast sprinted across the diagonal length of the floor, decelerated, touched the cone, and then turned around and repeated the run for a total of five passes ending in the opposite corner. Time measurement was recorded with the Brower Timing System, placed in both corners.

xi. A 20-yard (18.3 m) sprint test modified from (Sleeper et al., 2012). Performed on a gymnastic running mattress, the participants completed their personalized running approach between 19–25 m, with springboard/trampet, vaulting table, and high mat placed at the other end of the runway. The running approach in competitions is always the same for each gymnast but with a maximum distance of 25 m (FIG MAG, 2017; FIG WAG, 2017; UEG, 2017). The timing gates were placed 1 m in front of the springboard/trampette and 20 yards (18.3 m) along the runway. A better of two trials was recorded. After take-off from the springboard or trampette, the gymnast performed a handspring on the high mat.

xii. The repeated tucked backward saltos gymnast performed ten connected saltos on the fiber track as rapidly as possible.

xiii. A press handstand was from a straddle position with hands on the floor. From the support press to the handstand, it was done with a minimum 30° from vertical, without touching the floor. If the seated press couldn’t be performed, the gymnast started in a standing straddle pike position with hands on the floor. Points were obtained for difficulty, quality and the number of presses.

xiv. Only MAG gymnastics performed the handstand push-up test. The gymnast started in a handstand position on parallels spaced with hands shoulder-width apart and 6-12 inches (15-30 cm) from the wall. The gymnast's feet touched the wall, so balance was not needed. The handstand push-up was performed with the body in a straight, vertical position. The gymnast lowered himself until he touched the floor with his head. The gymnast had to extend the elbows between repetitions (Sleeper et al., 2016).

xv. The WAG and TG gymnastics performed the push-up test. The gymnast started with her hands shoulder-width apart on a low beam and thumbs placed directly under the shoulders, and the elbows positioned away from her side. Feet were together on another beam. The push-up was performed with the body in a straight, horizontal position. The torso had to touch a 2.5 cm block placed directly under her chest and the elbows extended between the trials (Sleeper et al., 2012).

xvi. A ring hold test for MAG. Arm length was recorded and arms marked every 5 cm starting at the pectoralis fold and progressing distally. The gymnast started in a position with the axilla resting on the still rings, with the still rings placed at a height where the gymnast could bend his knees and hang. The gymnast lifted his legs off the floor and should be suspended by the rings for 5 sec with his shoulders abducted to 90° and elbows straight. If completed, the rings were moved to the next distal mark, and the gymnast continued until he could not perform the tested length. The raw test score is the distance of the last completed hang divided by the length of the gymnast's arms (Sleeper et al., 2016).

xvii. Kip to handstand on low bar for WAG. The handstand was considered valid if the position was 30° from vertical and elements connected (Brynjolfsson & Arnadottir, 2014). Pirouette balance tested the time gymnasts could perform a pirouette position on the toes with arms down by the sides and free leg forward in a toe to knee position (Hakonardottir, 2018).

Table 2

The tests used by discipline and gender are shown.

Men artistic MAG	Women artistic WAG	TeamGym TG
Height and weight	Height and weight	Height and weight
Body composition	Body composition	Body composition
Grip strength	Grip strength	Grip strength
Rope Climb Test	Rope Climb Test	Rope Climb Test
*Overgrip Pull-ups	*Overgrip Pull-ups	*Overgrip Pull-ups
*Hanging Pikes	*Hanging Pike	*Hanging Pike
*Handstand Test on floor	*Handstand Test floor	*Handstand Test on floor
Y balance test	Y balance test	Y balance test
*Shoulder Flexibility Test	*Shoulder Flexibility Test	*Shoulder Flexibility
*Splits Tests	*Splits Tests	*Splits Tests
*Vertical Jump Test	*Vertical Jump Test	*Vertical Jump Test
*Agility Test	*Agility Test	*Agility Test
The 20 Yard Sprint Test	The 20 Yard Sprint Test	The 20 Yard Sprint Test
** Handstand push-ups	** Push-ups	** Push-ups
Press into handstand	Press into handstand	Press into handstand
Repeated back saltos	Repeated back saltos	Repeated back saltos
Rings Hold Test	Kip handstand on low bar	Pirouette balance

* GFMT and MGFMT scored males and females differently (Sleeper et al., 2012, 2016).

** Different tests for MAG and TG males.

2.3.5 Psychological measurements

The primary aim of the psychological measurements was to offer a detailed description of the psychological skills used by gymnasts to control their behavioral strategies in training and competition context.

The Test of Performance Strategies Questionnaire (TOPS) (P. R. Thomas et al., 1999) was used to measure the skills and strategies used by sportspersons and consists of two scales, practice and competition. Each scale has eight subscales. Activation, relaxation, imagery, goal setting, emotional control, self-talk, automaticity, are the same for both scales, but attentional control is in competition part and concentration in the practice part (Katsikas et al., 2011) The responses were from (1) never to (5) always on a Likert scale. The Sport Mental Toughness Questionnaire (SMTQ) (Sheard et al., 2009) was used to measure mental toughness and has three subscales: constancy, control and confidence. The responses were (1) not at all true, to (4) very true. A higher score indicated higher mental toughness.

The Sport Anxiety Scale – 2 Questionnaire (SAS-2) (Smith et al., 2006) was used to measure cognitive and somatic anxiety in sports performance. Three subscales are somatic anxiety, concentration, and worry, all having five items each. The response was (1) not at all, to (4) very much. A higher score meant more anxiety.

2.3.6 Procedures

The gymnast participated in two testing sessions four months apart, before and after the competition period. Participants were experienced in performing testing in training. All participants received written information about the tests prior and gave their informed consent of participation. Reykjavik University sport science students performed the test that was executed in the most convenient order for the testing process. All participants performed the tests barefooted, wearing gymnastic training clothes and a numbered vest to identify them. After the physical test, the psychological questionnaires were presented, and participants were asked to respond sincerely at the gym or by email link online at home.

2.3.7 Equipment

Measurements took place in three clubs arranged by the FSÍ, with artistic and TeamGym gymnastic facilities. Equipment used at the gym were asymmetric bars, parallel bars, rings, rope, two low beams, floor parallel bars, floor 12x12, vaulting runway with springboard/trampette, vaulting table, and high mat, clear floor space, and fiber track. Equipment brought to the gym were time gates (Brower timing system, Utah, USA), jump mat (FSL scoreboards, Cookstown, Northern Ireland), hand dynamometer (Venier, Oregon, USA), a computer, weight, and height portable stadiometer scale (Seca, Hamburg, Germany), body composition machine with a computer (Tanita BC 418, Amsterdam, The Netherlands), measuring tapes, markers, stopwatches, and numbered vests. The psychological questionnaires were obtained and stored by QuestionPro (Seattle, USA).

2.3.8 Statistical analysis

Statistical analysis was performed with the Statistical Package for the Social Sciences SPSS statistics 27 (IBM, Washington, USA). The basic descriptive statistics (mean and standard deviation) were calculated. The Independent samples t-test was used to compare the means of two groups in order to determine whether there is statistical evidence that the associated population means are significantly different. The t-test is based on the ratio of the difference between groups to the standard error of the difference (Norman & Streiner, 2008) and was used to compare age, gender, and discipline. The effect sizes (ES) of the differences were calculated and interpreted following literature recommendations >0.2 small, >0.5 moderate, >0.8 large. The Paired samples t-test was used to compare the means of physical tests before and after the competition period from the same individual.

2.4 Results

Table 3 presents the basic descriptors of the variables by age (junior/senior) for the anthropometric and body composition measurements. Nine variables showed a large ES (Cohen's d>0.80) or close in differentiating between junior and senior gymnasts. In order of decreasing ES value, these variables were: right arm muscle and muscle mass (ES=1.35), left arm muscle (ES=1.33), weight (ES=1.23), BMI (ES=1.17), right leg muscle (ES=1.16), left leg muscle (ES=1.05), height (ES=0.93), and arm length to finger (ES=0.89). Senior scores are higher than juniors.

Table 3

Mean and standard deviation of each anthropometry and body composition parameters for age. T-test, p-value, and effect size (Cohen´s d) are shown.

Variable	Junior (J) n=53 M ± SD	Senior (S) n=22 M ± SD	*T*	*p*	Cohen's d	Differences
Height (m)	164.35 ± 10.88	173.00 ± 7.46	3.414	0.001	0.93	J<S
Weight (kg)	54.52 ± 12.25	69.80 ± 12.52	4.895	<0.001	1.23	J<S
BMI (kg/m2)	19.93 ± 2.81	23.15 ± 2.68	4.586	<0.001	1.17	J<S
Muscle mass (kg)	42.48 ± 9.42	56.05 ± 10.61	5.468	<0.001	1.35	J<S
Fat (%)	20.17 ± 5.31	16.66 ± 4.74	2.688	0.009	0.70	J>S
Right leg muscle (kg)	7.10 ±1.83	9.31 ± 1.99	4.635	<0.001	1.16	J<S
Left leg muscle (kg)	6.80 ±1.70	8.87 ± 2.23	4.376	<0.001	1.05	J<S
Right arm muscle (kg)	1.99 ±0.66	3.05 ± 0.89	5.698	<0.001	1.35	J<S
Left arm muscle (kg)	2.03 ±0.64	3.07 ± 0.90	5.641	<0.001	1.33	J<S
Arm length to fist (cm)	49.57 ±5.40	51.59 ± 4.14	1.574	0.120	0.42	n.s.
Arm length to finger (cm) **	60.63 ±3.75	57.40 ± 3.49	1.334	0.224	0.89	n.s.
Leg length (cm)	87.07 ±5.92	91.02 ± 4.71	2.789	0.007	0.74	J<S

Note. ** n_J=4, n_S=5; n.s.; not significant

Table 4 presents the basic descriptors of the physical fitness parameters by age (junior/senior) for the physical test. Six variables showed a large ES (Cohen's *d*>0.80) or close in differentiating between junior and senior gymnasts. In order of decreasing ES value, these variables were: rings hold MAG (ES=1.41), grip strength right (ES=1.24), pirouette TG (ES=1.19), grip strength left (ES=1.11), push-up WAG/TG points (ES=0.92), and push-up WAG/TG numbers (ES=0.80). Senior scores are higher than juniors, except for the number of push-ups.

Table 4

Mean and standard deviation of the physical fitness parameters for age. T-test, p-value, and effect size (Cohen´s d) are shown.

Variable	Junior (J) n=53 M ± SD	Senior (S) n=23 M ± SD	*T*	*p*	Cohen's d	Differences
Grip strength left (N)	211.14 ±65.95	302.66 ± 95.86	4.818	<0.001	1.11	J<S
Grip strength right (N)	220.86 ±86.08	336.44 ± 99.52	5.127	<0.001	1.24	J<S
Y balance	104.25 ±8.78	107.17 ± 9.29	1.313	0.193	0.32	n.s.
Handstand (sec)	15.66 ±20.02	35.16 ± 30.62	3.300	0.001	0.75	J<S
Handstand (point)	2.25 ±2.07	4.14 ± 2.83	3.202	0.002	0.76	J<S
Rope climb (point)	5.32 ±3.02	7.43 ± 2.905	2.837	0.006	0.71	J<S
Hand. push up MAG (number)**	10.25 ±5.19	9.60 ± 4.51	0.201	0.846	0.13	n.s.
Hand. push up MAG (points) **	4.00 ±2.00	4.00 ± 1.58	0.000	1.000	0.00	n.s.
Push up WAG/TG (number)***	60.63 ±3.75	57.40 ± 3.49	2.885	0.005	0.80	J>S
Push up WAG/TG (point)***	6.04 ±2.73	8.17 ± 1.82	3.051	0.003	0.92	J<S
Pull ups (number)	5.62 ±5.56	10.23 ± 6.43	3.119	0.003	0.77	J<S
Pull ups (point)	2.94 ±2.62	4.91 ± 3.04	2.812	0.006	0.69	J<S
Hanging pikes (number)	16.23 ± 11.95	23.96 ± 11.90	2.594	0.011	0.65	J<S
Hanging pikes (point)	4.02 ± 2.76	5.48 ± 2.75	2.123	0.037	0.53	J<S
Vertical jump (point)*	3.31 ±1.78	4.87 ± 1.98	3.386	0.001	0.39	J<S
Right split (number)*	-2.97 ±14.45	-4.92 ± 19.05	0.477	0.635	0.12	n.s.
Left split (number)*	-6.88 ±10.88	-4.09 ± 18.48	0.809	0.421	0.18	n.s.
Middle split (number)****	-14.91 ±15.41	-16.91 ± 16.92	0.711	0.479	0.18	n.s.
Hips flexibility (point)****	3.98 ±1.39	4.36 ± 1.84	0.977	0.383	0.23	n.s.
Shoulder flexibility (number)*	35.51 ±12.58	34.20 ± 15.59	0.380	0.705	0.09	n.s.
Shoulder flexibility (point)*	4.36 ±2.27	4.41 ± 2.84	0.081	0.935	0.02	n.s.
Sprint (sec)*	2.77 ±0.45	2.54 ± 0.60	1.830	0.071	0.44	n.s.
Sprint (point)*	5.84 ±1.98	7.10 ± 1.67	2.543	0.013	0.69	J<S
Agility (sec)***	17.68 ±3.85	17.00 ± 3.98	0.674	0.499	0.17	n.s.
Agility (point)***	6.88 ±1.62	7.29 ± 1.93	0.914	0.364	0.23	n.s.
Salto (number)*****	18.72 ±8.81	14.62 ± 4.99	1.938	0.057	0.57	n.s.
Salto (point)*****	3.36 ±3.95	5.42 ± 4.05	1.851	0.069	0.52	n.s.
Press to handstand	2.32 ±2.77	3.65 ± 3.20	1.835	0.71	0.44	n.s.
Rings hold MAG (point)**	6.00 ±0.00	7.00 ± 1.00	1.972	0.89	1.41	n.s.
Pirouette TG (point)□	7.50 ±2.96	10.00 ± 0.00	2.776	0.009	1.19	J<S
Kip handstand (point)□□	4.25 ±3.77	5.14 ± 4.38	0.520	0.608	0.22	J<S

Note. * n_J=53, n_S=22; ** n_J=4, n_S=5; *** n_J=48, n_S=18; **** n_J=50, n_S=22; ***** n_J=43, n_S=20; □ n_J=28, n_S=11; □□ n_J=20, n_S=7
n.s., not significant

Table 5 presents the basic descriptors of the variables by gender (male/female) for the anthropometric and body composition measurements. Ten variables showed a large ES (Cohen's *d*>0.80) or close in differentiating between male and female gymnasts. In order of decreasing ES value, these variables were: left arm muscle (ES=2.68), height (ES=2.60), left leg muscle (ES=2.53), muscle mass (ES=2.51), right leg muscle (ES=2.48), fat (ES=2.47), arm length to fist (ES=1.80), leg length (ES=1.79), weight (ES=1.62), and BMI (ES=0.83). Males score higher than females in all but fat percentages.

Table 5

Mean and standard deviation of each anthropometry and body composition parameters for gender. T-test, p-value, and effect size (Cohen´s d) are shown.

Variable	Male (M) n=26 M ± SD	Female (F) n=49 M ± SD	*t*	*p*	Cohen's d	Differences
Height (m)	177.37 ± 5.98	161.32 ± 8.19	8.810	<0.001	2.60	M>F
Weight (kg)	70.79 ± 10.73	52.75 ± 11.47	6.624	<0.001	1.62	M>F
BMI (kg/m2)	22.47 ± 2.98	20.03 ± 2.89	3.446	<0.001	0.83	M>F
Muscle mass (kg)	58.61 ± 7.56	40.01 ± 7.27	10.399	<0.001	2.51	M>F
Fat (%)	13.61 ± 3.04	22.08 ± 3.77	9.859	<0.001	2.47	M<F
Right leg muscle (kg)	9.97 ±1.38	6.57 ± 1.36	10.225	<0.001	2.48	M>F
Left leg muscle (kg)	9.61 ±1.36	6.24 ± 1.30	10.552	<0.001	2.53	M>F
Right arm muscle (kg)	3.26 ±0.63	3.05 ± 0.89	11.605	<0.001	0.27	M>F
Left arm muscle (kg)	3.29 ±0.64	1.83 ± 0.43	11.637	<0.001	2.68	M>F
Arm length to fist (cm)	54.65 ±3.40	47.78 ± 4.21	7.176	<0.001	1.80	M>F
Arm length to finger (cm) *	58.83 ±3.77					
Leg length (cm)	93.52 ±4.91	85.42 ± 4.12	7.577	<0.001	1.79	M>F

Note. * n_m=9, n_f=0
n.s., not significant

Table 6 presents the basic descriptors of the variables by gender (male/female) for the physical test. Eight variables showed a large ES (Cohen's *d*>0.80) or close in differentiating between male and female gymnasts. In order of decreasing ES value, these variables were: grip strength right (ES=2.62), grip strength left (ES=2.59), vertical jump (ES=2.54), sprint point (ES=1.62), pull-ups number (ES=1.52), pull-ups points (ES=1.37), rope climb (ES=1.27), and right split (ES=0.94) Males scored higher than females in strength, but females higher in split flexibility.

Table 6

Mean and standard deviation of the physical fitness parameters for gender. T-test, p-value, and effect size (Cohen´s d) are shown.

Variable	Male (M) n=26 M ± SD	Female (F) n=49 M ± SD	*t*	*p*	Cohen's d	Differences
Grip strength left (N) **	332.21 ±68.36	187.38 ± 39.82	11.694	<0.001	2.59	M>F
Grip strength right (N) **	365.29 ±72.50	195.53 ± 61.09	10.843	<0.001	2.62	M>F
Y balance **	106.85 ±9.55	104.18 ± 8.60	1.245	0.217	0.29	n.s.
Handstand (sec)	31.73 ±32.32	15.96 ± 18.30	2.723	0.008	0.60	M>F
Handstand (point)	3.42 ±2.72	2.48 ± 2.27	1.593	0.116	0.38	n.s.
Rope climb (point) **	8.11 ±2.36	4.78 ± 2.86	5.165	<0.001	1.27	M>F
Handst. push up MAG (number) *	9.89 ±4.51					
Handst. push up MAG (points) *	4.00 ±1.66					
Push up WAG/TG (number) □	41.00 ±16.52	31.44 ± 16.60	2.088	0.041	0.58	M>F
Push up WAG/TG (point) □	7.61 ±1.94	6.25 ± 2.83	1.875	0.065	0.56	n.s.
Pull ups (number)	12.19 ±6.39	4.20 ± 3.81	6.783	<0.001	1.52	M>F
Pull ups (point)	5.77 ±2.98	2.31 ± 1.96	6.001	<0.001	1.37	M>F
Hanging pikes (number) **	21.52 ± 15.86	16.94 ± 9.77	1.558	0.124	0.35	n.s.
Hanging pikes (point) **	4.33 ± 3.40	4.53 ± 2.48	0.290	0.772	0.07	n.s.
Vertical jump (point) ***	5.81 ±1.24	2.65 ± 1.25	10.586	<0.001	2.54	M>F
Right split (number) *****	-12.63 ±17.12	1.50 ± 12.60	4.030	<0.001	0.94	M<F
Left split (number) ******	-12.58 ±15.23	-2.51 ± 11.12	3.256	0.002	0.76	M<F
Middle split (number) ****	-20.50 ±22.28	-11.74 ± 9.54	2.325	0.023	0.51	M<F
Hips flexibility (point) ♦♦♦	4.40 ±2.02	3.94 ± 1.21	1.223	0.225	0.28	n.s.
Shoulder flexibility (number)	30.62 ±13.66	37.52 ± 12.82	2.169	0.033	0.52	M<F
Shoulder flexibility (point)	3.92 ±2.42	4.61 ± 2.43	1.171	0.245	0.28	n.s.
Sprint (sec) ***	2.46 ±0.51	2.84 ± 0.46	3.371	0.001	0.78	M>F
Sprint (point) ♦♦♦	7.73 ±0.87	5.33± 1.90	6.074	<0.001	1.62	M>F
Agility (sec) ****	16.47 ±3.53	18.06 ± 3.98	1.684	0.097	0.42	n.s.
Agility (point) ♦	7.68 ±1.84	6.61 ± 1.53	2.584	0.012	0.63	M>F
Salto (number) □□□□□	17.55 ±7.26	17.34 ± 8.48	0.096	0.923	0.03	n.s.
Salto (point) □□□□	5.26 ±4.41	3.23 ± 3.66	1.905	0.062	0.50	n.s.
Press to handstand **	3.33 ±3.51	2.39 ± 2.57	1.344	0.183	0.31	n.s.
Rings hold MAG (point) *	6.56 ±0.88					
Pirouette TG (point) □□	8.78 ±2.49	7.71 ± 2.92	1.229	0.227	0.39	n.s.
Kip handstand (point) □□□		4.48 ± 3.86				

Note. * n_m=9, n_f=0; ** n_m=27, n_f=49; *** n_m=27, n_f=48; **** n_m=26, n_f=46; ***** n_m=26, n_f=47; ****** n_m=26, n_f=48; □ n_m=18, n_f=48 □□ n_m=18, n_f=21; □□□ n_m=0, n_f=27; □□□□ n_m=23, n_f=35; □□□□□ n_m=23, n_f=40; ♦ n_m=25, n_f=44; ♦♦ n_m=26, n_f=45; ♦♦♦ n_m=25, n_f=48
n.s., not significant

Table 7 presents the basic descriptors of the variables by discipline (Artistic/TeamGym) for the anthropometric measurements. Ten variables showed a large ES (Cohen's *d*>0.80) or close in differentiating between Artistic and TeamGym gymnasts. In order of decreasing ES value, these variables were: arm length to fist (ES=1.78), weight (ES=0.99), height (ES=0.97), left leg muscles (ES=0.90), right leg muscle (ES=0.86), and BMI (ES=0.85). TeamGym scored higher than artistic gymnasts on all accounts.

Table 7

Mean and standard deviation of each anthropometry and body composition parameters for discipline. T-test, p-value, and effect size (Cohen´s d) are shown.

Variable	Artistic (A) n=37 M ± SD	TeamGym (T) n=38 M ± SD	*t*	*p*	Cohen’s d	Differences
Height (m)	162.14 ± 10.70	171.51 ± 8.56	4.195	<0.001	0.97	T>A
Weight (kg)	52.65 ± 14.56	65.19 ± 10.58	4.273	<0.001	0.99	T>A
BMI (kg/m2)	19.63 ± 3.22	22.08 ± 2.53	3.680	<0.001	0.85	T>A
Muscle mass (kg) *	42.18 ± 11.82	50.42 ± 9.84	3.289	0.002	0.76	T>A
Fat (%) *	18.10 ± 4.46	20.11 ± 5.98	1.634	0.106	0.38	n.s.
Right leg muscle (kg) *	6.86 ±2.12	8.56 ± 1.80	3.740	<0.001	0.86	T>A
Left leg muscle (kg) *	6.52 ±2.08	8.24 ± 1.72	3.905	<0.001	0.90	T>A
Right arm muscle (kg) *	2.06 ±0.92	2.52 ± 0.78	2.312	0.024	0.54	T>A
Left arm muscle (kg) *	2.10 ±0.93	2.55 ± 0.75	2.320	0.023	0.53	T>A
Arm length to fist (cm)	46.70 ±4.25	53.53 ± 3.38	7.716	<0.001	1.78	T>A
Arm length to finger (cm) **	58.83 ±3.77					
Leg length (cm)	86.47 ±5.54	89.93 ± 5.71	2.665	0.009	0.62	T>A

Note. * n_a=36, n_t=39; ** n_a=9, n_t=0
n.s., not significant

Table 8 presents the basic descriptors of the variables by discipline (Artistic/TeamGym) for the physical test. Ten variables showed a large ES (Cohen's *d*>0.80) or close in differentiating between Artistic and TeamGym gymnasts. In order of decreasing ES value, these variables were: hanging pikes points (ES=1.41), hanging pikes number (ES=1.23), pull-ups point (ES=1.11), left split (ES=1.09), sprint point (ES=1.03), right split (ES=0.97), pull-ups number (ES=0.95), middle split (ES=0.91), hips flexibility and salto (ES=0.82) Artistic gymnasts scored higher than TeamGym in hanging strength and flexibility, but TeamGym scored higher in grip strength and running speed.

Table 8

Mean and standard deviation of the physical fitness parameters for discipline. T-test, p-value, and effect size (Cohen´s d) are shown.

Variable	Artistic (A) n=37 M ± SD	TeamGym (T) n=38 M ± SD	*t*	*p*	Cohen’s d	Differences
Grip strength left (N)	215.98 ±87.96	260.52 ± 80.54	2.304	0.024	0.53	A<T
Grip strength right (N)	224.55 ±107.21	285.53 ± 93.62	2.645	0.010	0.61	A<T
Y balance	106.78 ±6.19	103.56 ± 10.84	1.578	0.119	0.36	n.s.
Handstand (sec)	30.96 ±30.79	12.64 ± 13.64	3.384	0.001	0.77	A>T
Handstand (point) **	3.65 ±2.95	1.97 ± 1.46	3.099	0.003	0.72	A>T
Rope climb (point)	6.49 ±3.48	5.46 ± 2.74	1.441	0.154	0.33	n.s.
Handst. push up MAG (number) *	9.89 ±4.51					
Handst. push up MAG (points) *	4.00 ±1.66					
Push up WAG/TG (number) ****	38.89 ±17.07	30.47 ± 16.25	2.036	0.046	0.51	A>T
Push up WAG/TG (point) ****	7.57 ±2.77	5.92 ± 2.41	2.582	0.012	0.64	A>T
Pull ups (number) ***	9.68 ±6.58	4.34 ± 4.39	4.141	<0.001	0.95	A>T
Pull ups (point) *****	4.97 ±2.96	2.16 ± 2.02	4.798	<0.001	1.11	A>T
Hanging pikes (number)	25.27 ± 13.50	12.21 ± 6.68	5.389	<0.001	1.23	A>T
Hanging pikes (point)	6.14 ± 2.82	2.87 ± 1.67	6.173	<0.001	1.41	A>T
Vertical jump (point) ***	3.54 ±1.89	4.03 ± 2.03	1.070	0.288	0.25	n.s.
Right split (number) □	3.50 ±12.44	-10.38 ± 15.84	4.155	<0.001	0.97	A>T
Left split (number) **	0.43 ±12.14	-12.53 ± 11.66	4.682	<0.001	1.09	A>T
Middle split (number) □□	-8.31 ±10.70	-21.50 ± 17.44	3.870	<0.001	0.91	A>T
Hips flexibility (point) (□□□	4.68 ±1.08	3.50 ± 1.72	3.513	<0.001	0.82	A>T
Shoulder flexibility (number) ***	37.09 ±12.57	33.21 ± 14.13	1.258	0.212	0.29	n.s.
Shoulder flexibility (point) ***	4.95 ±2.45	3.82 ± 2.31	2.056	0.043	0.47	A>T
Sprint (sec) □□□□	2.78 ±0.54	2.63 ± 0.47	1.254	0.214	0.30	n.s.
Sprint (point) □□□□□	5.29 ±2.14	7.11± 1.28	4.380	<0.001	1.03	A<T
Agility (sec) ♦	17.02 ±5.39	17.92 ± 1.34	0.990	0.326	0.23	n.s.
Agility (point) ♦♦	6.45±1.95	7.50 ± 1.30	2.638	0.010	0.63	A<T
Salto (number) ♦♦♦	14.36 ±6.81	21.23 ± 7.83	3.724	<0.001	0.94	A>T
Salto (point) ♦♦♦♦	5.53 ±4.00	2.43 ± 3.54	3.122	0.003	0.82	A>T
Press to handstand	3.84 ±3.70	1.67 ± 1.36	3.428	<0.001	0.78	A>T
Rings hold MAG (point) *	6.56 ±0.88					
Pirouette TG (point) ♦♦♦♦♦		8.21 ± 2.75				
Kip handstand (point) *♦		4.48 ± 3.86				

Note. * n_a=9, n_t=0; ** n_a=37, n_t=37; *** n_a=37, n_t=38; **** n_a=28, n_t=38; ***** n_a=36, n_t=38; □ n_a=36, n_t=37; □□ n_a=36, n_t=36; □□□ n_a=37, n_t=36; □□□□ n_a=36, n_t=39; □□□□□ n_a=35, n_t=36; ♦ n_a=35, n_t=37; ♦♦ n_a=33, n_t=36; ♦♦♦ n_a=35, n_t=28; ♦♦♦♦ n_a=30, n_t=28; ♦♦♦♦♦ n_a=0, n_t=39; *♦ n_a=27, n_t=0
n.s., not significant

Table 9 lists the basic descriptive statistics (mean and standard deviation) and t-value, p-value, and effect size for all TOPS sub-scales, both in practice and competition. There were differences between juniors and seniors in only two sub-scales studied, activation in practice and imagery in competition. Seniors scored higher in activation and juniors in imagery.

Table 9

Mean, and standard deviation of the Test of Performance Strategies Questionnaire (TOPS) for age, T-test, p-value, effect size (Cohen´s d) are shown, and differences between juniors and seniors for each sub-scale.

	Junior (J) n=43 M ± SD	Senior (S) n=25 M ± SD	t	p	Cohen's d	Differences
Practice						
Goal setting (n_J=44)	3.38 ± 0.88	3.56 ± 0.86	0.846	0.802	0.21	n.s.
Relaxation	2.30 ± 0.63	2.75 ± 0.89	2.449	0.126	0.58	n.s.
Automaticity (n_J=42)	3.40 ± 0.54	3.30 ± 0.43	0.820	0.317	0.21	n.s.
Activation (n_J=41)	3.01 ± 0.61	3.12 ± 0.85	0.629	0.031	0.15	J<S
Imagery (n_J=42)	3.41 ± 0.65	3.38 ± 0.79	0.173	0.124	0.04	n.s.
Self-talk (n_J=44)	3.60 ± 0.68	3.85 ± 0.85	1.330	0.105	0.33	n.s.
Emotional control	3.24 ± 0.84	3.42 ± 1.03	0.790	0.130	0.19	n.s.
Attentional control	3.48 ± 0.64	3.73 ± 0.70	1.480	0.597	0.37	n.s.
Competition						
Goal setting (n_J=42)	3.76 ± 0.90	3.71 ± 0.80	0.238	0.989	0.06	n.s.
Relaxation	3.40 ± 0.91	3.62 ± 0.90	0.963	0.710	0.24	n.s.
Automaticity	2.84 ± 0.65	3.00 ±0.48	1.091	0.289	0.28	n.s.
Activation (n_S=22)	4.08 ± 0.60	4.34 ± 0.56	1.757	0.935	0.44	n.s.
Imagery (n_J=42)	3.80 ± 0.57	3.72 ± 0.86	0.482	0.014	0.11	J>S
Self-talk (n_J=41)	3.55 ± 0.84	3.75 ± 0.82	0.923	0.962	0.24	n.s.
Emotional control (n_J=44)	3.62 ± 0.79	3.80 ± 0.94	0.842	0.150	0.21	n.s.
Negative thinking (n_J=42)	3.88 ± 0.75	4.09 ± 0.70	1.134	0.746	0.29	n.s.

Note. n.s., not significant.

Table 10 lists the basic descriptive statistics (mean and standard deviation) and t-value, p-value, and effect size for all TOPS sub-scales, both in practice and competition. There were differences between males and females in only one sub-scales studied; self-talk in practice, where females scored higher than males.

Table 10

Mean, and standard deviation of the Test of Performance Strategies Questionnaire (TOPS) for gender, T-test, p-value, effect size (Cohen´s d) are shown, and differences between males and females for each sub-scale.

	Male (M) n=24 M ± SD	Female (F) n=44 M ± SD	t	p	Cohen's d	Differences
Practice						
Goal setting (n_f=45)	3.51 ± 0.74	3.41 ± 0.94	0.473	0.421	0.12	n.s.
Relaxation	2.67 ± 0.89	2.35 ± 0.67	1.644	0.170	0.41	n.s.
Automaticity (n_f=43)	3.40 ± 0.57	3.33 ± 0.47	0.742	0.452	0.13	n.s.
Activation (n_m=22)	3.01 ± 0.84	3.06 ± 0.64	0.213	0.124	0.07	n.s.
Imagery (n_f=43)	3.44 ± 0.65	3.38 ± 0.73	0.333	0.290	0.09	n.s.
Self-talk (n_f=45)	3.58 ± 0.92	3.75 ± 0.64	0.880	0.016	0.22	M<F
Emotional control	3.69 ± 0.81	3.10 ± 0.91	2.670	0.644	0.69	n.s.
Attentional control (n_m=23, n_f=45)	3.82 ± 0.72	3.45 ± 0.62	2.184	0.749	0.55	n.s.
Competition						
Goal setting (n_m=23)	3.52 ± 0.87	3.86 ± 0.84	1.540	0.830	0.40	n.s.
Relaxation	3.93 ± 0.86	3.24 ± 0.84	3.205	0.792	0.81	n.s.
Automaticity	2.96 ± 0.42	2.86 ±0.67	0.625	0.134	0.18	n.s.
Activation (n_m=22, n_f=45)	4.22 ± 0.55	4.16 ± 0.62	0.387	0.508	0.10	n.s.
Imagery (n_m=22, n_f=45)	3.61 ± 0.78	3.85 ± 0.62	1.340	0.110	0.34	n.s.
Self-talk (n_f=42)	3.30 ± 0.85	3.82 ± 0.77	2.507	0.449	0.64	n.s.
Emotional control (n_f=45)	4.04 ± 0.72	3.50 ± 0.85	2.663	0.109	0.69	n.s.
Negative thinking (n_s=43)	3.84 ± 0.80	3.84 ± 0.80	1.764	0.020	0.00	n.s.

Table 11 lists the basic descriptive statistics (mean and standard deviation) and t-value, p-value, and effect size for all TOPS sub-scales, both in practice and competition. There were differences between Artistic and TeamGym in only one sub-scales studied, emotional control in practice, where TeamGym scored higher than artistic gymnasts.

Table 11

Mean, and standard deviation of the test of Performance Strategies Questionnaire (TOPS) for discipline, T-test, p-value, effect size (Cohen´s d) are shown, and differences between Artistic and TeamGym for each sub-scale.

	Artistic (A) n=36 M ± SD	TeamGym (T) n=32 M ± SD	t	p	Cohen's d	Differences
Practice						
Goal setting (n_t=33)	3.32 ± 1.00	3.58 ± 0.70	1.225	0.121	0.30	n.s.
Relaxation	2.53 ± 0.85	2.39 ± 0.66	0.737	0.245	0.18	n.s.
Automaticity (n_a=34, n_t=33)	3.31 ± 0.46	3.42 ± 0.55	0.936	0.510	0.22	n.s.
Activation (n_a=35, n_t=31)	2.91 ± 0.77	3.20 ± 0.61	1.663	0.299	0.42	n.s.
Imagery (n_t=31)	3.32 ± 0.79	3.49 ± 0.57	1.009	0.054	0.25	n.s.
Self-talk (n_t=33)	3.74 ± 0.80	3.64 ± 0.69	0.589	0.711	0.13	n.s.
Emotional control (n_a=35, n_t=33)	3.19 ± 1.02	3.42 ± 0.77	1.048	0.066	0.26	A<T
Attentional control	3.63 ± 0.69	3.51 ± 0.66	0.759	0.537	0.18	n.s.
Competition						
Goal setting (n_a=35)	3.64 ± 0.99	3.86 ± 0.68	1.068	0.106	0.26	n.s.
Relaxation	3.38 ± 1.01	3.60 ± 0.77	1.033	0.087	0.25	n.s.
Automaticity	2.82 ± 0.70	2.98 ±0.44	1.104	0.069	0.27	n.s.
Activation (n_t=31)	4.13 ± 0.62	4.23 ± 0.57	0.744	0.216	0.17	n.s.
Imagery (n_a=35)	3.84 ± 0.74	3.70 ± 0.61	0.883	0.157	0.20	n.s.
Self-talk (n_a=35, n_t=31)	3.70 ± 0.83	3.55 ± 0.84	0.736	0.861	0.18	n.s.
Emotional control (n_t=33)	3.48 ± 0.91	3.91 ± 0.71	2.153	0.065	0.53	n.s.
Negative thinking (n_a=35)	3.86 ± 0.77	4.07 ± 0.68	1.195	0.331	0.29	n.s.

Note. n.s., not significant.

Table 12 lists the basic descriptive statistics (mean and standard deviation) and t-value, p-value, and effect size (Cohen's d) for the Sport Mental Toughness Questionnaire (SMTQ) and the Sport Anxiety Scale 2 questionnaire (SAS-2) sub-scales. There was only one moderate difference between juniors and seniors in the sub-scales as regards to concentration disruption in the anxiety scale, where juniors scored higher than seniors.

Table 12

Mean and standard deviation of the Sport Mental Toughness Questionnaire (SMTQ) and the Sport Anxiety Scale 2 questionnaire (SAS-2) for age, T-test, p-value, and effect size (Cohen's *d)*, and differences between the juniors and seniors for each sub-scale.

	Junior (J) n=40 M ± SD	Senior (S) n=24 M ± SD	t	p	Cohen's d	Differences
SMTQ						
Confidence (n_s =22)	15.88 ± 3.86	18.68 ± 4.27	2.639	0.442	0.69	n.s.
Constancy (n_j =39, n_s =20)	13.03 ± 2.41	14.40 ± 1.96	2.201	0.304	0.62	n.s.
Control (n_j =41, n_s =22)	11.46 ± 2.93	12.18 ± 3.29	0.888	0.618	0.23	n.s.
Total (n_j =38, n_s =20)	40.47 ± 7.38	45.45 ± 8.00	2.372	0.510	0.65	n.s.
SAS-2						
Somatic anxiety (n_j =38)	10.39 ± 2.99	10.17 ± 3.10	0.288	0.430	0.07	n.s.
Worry (n_j =42)	11.40 ± 4.41	9.42 ± 4.15	1.799	0.901	0.55	n.s.
Concentration disruption (n_j =40)	7.20 ± 2.33	6.08 ± 1.44	2.111	0.003	0.58	J>S
Total (n_j =37)	28.54 ± 7.95	25.67 ± 7.43	1.414	0.780	0.37	n.s.

Note. n.s., not significant.

Table 13 lists the basic descriptive statistics (mean and standard deviation) and t-value, p-value, and effect size (Cohen's d) for all the Sport Mental Toughness Questionnaire (SMTQ) and the Sport Anxiety Scale 2 questionnaire (SAS-2) sub-scales. There were three differences between males and females in the sub-scales: control in SMTQ, where males scored higher than females. Females scored higher in the anxiety SAS-2 scale in two sub-scales: worry and concentration disruption. There was a large ES in all those sub-scales.

Table 13

Mean and standard deviation of the Sport Mental Toughness Questionnaire (SMTQ) and the Sport Anxiety Scale 2 questionnaire (SAS-2) for gender, T-test, p-value, and effect size (Cohen's *d)*, and differences between the males and females for each sub-scale.

	Male (M) n=21 M ± SD	Female (F) n=41 M ± SD	t	p	Cohen's d	Differences
SMTQ						
Confidence (n_m =22, n_f =40)	18.68 ± 3.62	15.88 ± 4.20	2.639	0.159	0.71	n.s.
Constancy (n_f =38)	13.76 ± 2.21	13.34 ± 2.43	0.655	0.548	0.18	n.s.
Control (n_m =22)	13.91 ± 1.51	10.54 ± 3.03	4.886	<0.001	1.41	M>F
Total (n_f =37)	46.19 ± 6.02	39.92 ± 8.00	3.122	0.107	0.89	n.s.
SAS-2						
Somatic anxiety	7.90 ± 2.14	11.54 ± 2.64	5.450	0.311	1.51	n.s.
Worry (n_m =23, n_f =43)	8.04 ± 2.92	12.09 ± 4.42	3.949	0.040	1.08	M<F
Concentration disruption (n_m =22, n_f =42)	5.73 ± 1.24	7.33 ± 2.26	3.091	<0.001	0.88	M<F
Total (n_f =40)	21.33 ± 4.48	30.60 ± 7.31	5.299	0.037	1.53	n.s.

Note. n.s., not significant.

Table 14 lists the basic descriptive statistics (mean and standard deviation) and t-value, p-value, and effect size (Cohen's d) for the Sport Mental Toughness Questionnaire (SMTQ) and the Sport Anxiety Scale 2 questionnaire (SAS-2) sub-scales. There were no differences between artistic and TeamGym in any sub-scales.

Table 14

Mean and standard deviation of the Sport Mental Toughness Questionnaire (SMTQ) and the Sport Anxiety Scale 2 questionnaire (SAS-2) for discipline, T-test, p-value, and effect size (Cohen's *d)*, and differences between the artistic and TeamGym for each sub-scale.

	Artistic (A) n=35 M ± SD	TeamGym (T) n=29 M ± SD	t	p	Cohen's d	Differences
SMTQ						
Confidence (n_a =33)	16.09 ± 4.39	17.76 ± 3.85	1.580	0.320	0.40	n.s.
Constancy (n_a =32, n_t =27)	13.38 ± 2.24	13.63 ± 2.50	0.413	0.711	0.10	n.s.
Control (n_a =33, n_t =30)	11.12 ± 3.02	12.37 ± 3.01	1.638	0.538	0.42	n.s.
Total (n_a =32, n_t =26)	40.75 ± 8.15	43.96 ± 7.34	1.559	0.390	0.41	n.s.
SAS-2						
Somatic anxiety (n_a =34, n_t =28)	10.35 ± 2.86	10.25 ± 3.24	0.133	0.935	0.03	n.s.
Worry (n_t =31)	11.09 ± 4.03	10.23 ± 4.79	0.791	0.665	0.19	n.s.
Concentration disruption	6.77 ± 2.06	6.79 ± 2.19	0.041	0.328	0.01	n.s.
Total (n_a =34, n_t =27)	27.91 ± 7.28	26.78 ± 8.55	0.559	0.866	0.14	n.s.

Note. n.s., not significant.

Table 15 presents the competition period's impact on anthropometry and body composition parameters. Two variables showed a large ES (Cohen's *d*>0.80) or close, in differentiating between pre- and post-measurements. In order of decreasing ES value, these variables were: arm length to finger (ES=1.48) and arm length to fist (ES=0.87). The arm length measurements were significantly more after the competition period.

Table 15

Mean ± standard deviation, for the pre- and post-intervention for anthropometric and body composition, %changes t-test, p-value, and effect size (Cohen´s d) are showed.

Variable	Competition period					
	Pre	Post	Δ%	t	P	ES
Height (m) (n =44)	167.18 ± 10.58	168.24 ± 9.61	1.06	3.490	0.001	0.10
Weight (kg) (n =44)	57.96± 12.52	60.16 ± 11.48	2.20	6.744	<0.001	0.18
BMI (kg/m2) (n =44)	20.51 ± 2.68	21.09 ± 2.49	0.58	5.018	<0.001	0.22
Muscle mass (kg) (n =43)	45.17±10.34	46.45±10.12	1.28	6.356	<0.001	0.13
Fat (%) (n =43)	19.52±5.32	19.35±5.58	-0.17	0.663	0.511	0.03
Right leg muscle (kg) (n =43)	7.57±2.00	7.77±1.90	0.20	2.240	0.030	0.10
Left leg muscle (kg) (n =43)	7.17±1.95	7.49±1.81	0.32	3.743	<0.001	0.17
Right arm muscle (kg) (n =43)	2.17±0.78	2.26±0.75	0.09	3.394	0.002	0.12
Left arm muscle (kg) (n =43)	2.21±0.76	2.28±0.75	0.07	3.546	<0.001	0.09
Arm length to fist (cm) (n =44)	50.10±5.25	55.86±7.80	5.76	5.254	<0.001	0.87
Arm length to finger (cm) (n =5)	59.40±4.20	65.60±4.16	6.20	15.263	<0.001	1.48
Leg length (cm) (n =44)	88.49±5.57	87.59±7.17	-0.90	0.994	0.326	0.14

Table 16 presents the competition period's impact on physical measurements. Four variables showed a large ES (Cohen's *d*>0.80) or close in differentiating between pre- and post-measurements. In order of decreasing ES value, these variables were: Y balance (ES=4.71), left split (ES=1.86), right split (ES=1.73), and hips flexibility (ES=1.60). All the sub-tests were less after the competition period.

Table 16

Mean ± standard deviation, for the pre- and post-intervention for the physical fitness parameters, %changes t-test, p-value, and effect size (Cohen´s d) are showed.

Variable	Competition period					
	Pre	Post	Δ%	t	p	ES
Physical measurements						
Grip strength left (N) (n =44)	234.34 ± 81.15	226.67 ± 83.25	-7.67	1.205	0.235	0.09
Grip strength right (N) (n =44)	250.82± 90.10	228.84 ± 77.63	-21.98	3.397	0.001	0.26
Y balance (n =44)	105.54±8.66	47.34±15.18	-58.20	22.542	<0.001	4.71
Handstand (sec) (n =43)	23.09±25.35	31.48±28.21	8.39	3.275	0.002	0.31
Handstand (point) (n =43)	3.05±2.52	3.37±2.86	0.32	1.000	0.323	0.12
Rope climb (point) (n =39)	6.26±2.76	7.05±2.26	0.79	2.995	0.005	0.31
Handst. push up MAG (number) (n =5)	8.20±4.32	8.20±6.18	0.00	0.000	1.000	0.00
Handst. push up MAG (points) (n =5)	3.40±1.52	3.20±2.70	-0.20	0.232	0.828	0.09
Push up WAG/TG (number) (n =35)	35.63±15.32	33.60±10.41	-2.03	1.407	0.168	0.15
Push up WAG/TG (point) (n =35)	6.97±2.37	7.00±2.02	0.03	0.141	0.889	0.01
Pull ups (number) (n =42)	6.62±5.67	6.86±5.79	0.24	0.777	0.442	0.04
Pull ups (point) (n =41)	3.41±2.71	3.68±2.87	0.27	1.230	0.226	0.10
Hanging pikes (number) (n =44)	19.11±11.72	19.52±12.11	0.41	0.357	0.723	0.03

Hanging pikes (point) (n =44)	4.70±2.78	4.86±3.08	0.16	0.569	0.572	0.05
Vertical jump (point) (n =43)	3.74±1.71	3.84±1.95	0.10	0.550	0.585	0.05
Right split (number) (n =41)	-1.09±15.29	-23.73±10.48	-24.82	11.196	<0.001	1.73
Left split (number) (n =42)	-2.78±13.40	-24.45±9.53	-27.23	12.353	<0.001	1.86
Middle split (number) (n =39)	-13.76±16.94	-17.95±14.38	-31.71	1.762	0.086	0.27
Hips flexibility (point) (n =44)	4.36±1.43	1.93±1.61	-2.43	11.390	<0.001	1.60
Shoulder flexibility (number) (n =43)	33.47±11.83	36.53±13.19	3.06	2.602	0.013	0.24
Shoulder flexibility (point) (n =43)	4.02±2.17	3.86±2.17	-0.16	0.617	0.541	0.07
Sprint (sec) (n =43)	2.77±0.23	2.75±0.22	-0.02	4.087	<0.001	0.09
Sprint (point) (n =38)	6.11±1.87	6.79±1.85	0.68	4.668	<0.001	0.36
Agility (sec) (n =39)	17.65±3.19	18.52±0.99	0.87	1.769	0.085	0.37
Agility (point) (n =37)	7.32±1.40	6.86±1.27	-0.46	2.109	0.042	0.34
Salto (number) (n =34)	17.13±6.72	17.97±6.27	0.84	0.867	0.392	0.13
Salto (point) (n =33)	4.27±3.96	5.76±2.95	1.49	2.862	0.007	0.43
Press to handstand (n =42)	2.74±3.15	3.10±2.90	0.36	1.254	0.217	0.12
Rings hold MAG (point) (n =5)	6.20±0.45	5.60±3.36	-0.60	0.418	0.697	0.25
Pirouette TG (point) (n =18)	4.44±3.71	3.67±2.70	-0.77	0.792	0.439	0.24
Kip handstand (point) (n =21)	7.67±3.02	7.38±3.29	-0.29	0.439	0.666	0.09

2.5 Discussion

The objectives of the present study were: (1) to evaluate the difference in anthropometry, body composition and physical fitness in relation to age, gender and discipline; (2) to evaluate the difference in psychological skills in terms of age, gender and discipline; and (3) to identify the impact that the competition period had on physical measurements and psychological skills of Icelandic elite gymnasts. The study's main findings were:

2.5.1 Differences for age

The criteria for age were slightly different between disciplines, where WAG gymnasts become seniors at 16, compared to at 18 for MAG and TG. Test scores were converted to points in some physical fitness tests (Sleeper et al., 2012, 2016).

The seniors scored significantly higher in most anthropometric and body composition measurements than juniors (Table 3), as was expected. But, juniors scored moderately (ES=0.70) higher than seniors in fat percentages, explained by maturation in adolescence (Balyi & Way, 2005).

Seniors scored significantly higher than juniors in most physical fitness parameters, except for push-ups in WAG and TG discipline (Table 4), whereas juniors scored higher. This was not surprising, as physical ability and sports performance are known to increase during adolescence (Handelsman, 2017). Regarding the push-ups, MAG participated in handstand push-ups and did therefore not contribute to the push-ups data. WAG juniors scored high in the push-up test resulting in juniors scoring higher.

The Test of Performance Strategies Questionnaire (TOPS) evaluation was for sub-scales in practice and competition. In practice, seniors scored higher in activation and juniors in imagery in competition (Table 9). Thomas (1999) reported more automaticity in executing skills for older athletes than younger ones. Psychological skill training was successful in France for elite junior gymnasts, who increased their scores in three of four events (Fournier et al., 2005). the Sport Mental Toughness Questionnaire (SMTQ) or the Sport Anxiety Scale 2 questionnaire (SAS-2), did not differ between age (Table 12). Only in (SAS-2), juniors score moderately higher than seniors in concentration disruption, but it was not significant.

2.5.2 *Differences for gender*

There was a difference between genders, with males scoring higher than females in all anthropometric and body composition measurements except for fat percentages (Table 5). According to a previous study reported by Hansen (2019), TG males were 11% older, 8% taller, with a 19% greater body mass and 8% lower fat mass than the female TG gymnast.

In the physical fitness parameters, males scored higher in grip strength, vertical jumps, sprints, pull-ups, and rope climb. Females scored higher in split flexibility (Table 6). Unexpectedly, a previous TG study found that females ran 4% faster than males, and males showed a difference in running speed with age, with male seniors performing better than male juniors (Höög & Andersson, 2021). All participants are in the same gender comparison in this study, regardless of discipline. There are few overlaps in strength between males and females, and data have indicated that differences in upper body strength occur earlier than in the lower body (Gilliam et al., 1979; Round et al., 1999).

The Test of Performance Strategies Questionnaire (TOPS) evaluation was for sub-scales in practice and competition. In this current study, females scored higher than males in self-talk in practice (Table 10). According to Kristjánsdóttir (2018), females scored higher on anxiety than males. This suggests that females might use more psychological skills to overcome their anxiety. TeamGym gymnasts scored higher than artistic gymnasts in emotional control in practice. The Sport Mental Toughness Questionnaire (SMTQ) showed differences between genders, where males scored higher than females in the control sub-scale. In the Sport Anxiety Scale 2 questionnaire (SAS-2), females scored higher than males in both worry and concentration disruption (Table 13). Those findings are in accordance with a research of young competitive female gymnasts showing higher levels of trait anxiety than recreational gymnasts (Donti et al., 2012) and anxiety response to socially prescribed perfectionism for gymnastic competition for both males and females (Pineda-Espejel et al., 2020). Stenling et al. (2014) state that higher anxiety levels with females may be due to their different performance-approach goals or their desire to outperform others.

2.5.3 Differences for discipline

Three changes were made on the physical fitness test to coordinate between disciplines and make it more sport-specific. The 20 yards (18.3 m) running: A springboard/trampette, vaulting table, and a high mat was placed at the end of the runway. Gymnasts performed handspring entry which has the fastest run-up, according to Naundorf (2008), followed by Tsukahara vaults and then the Yurchenko vaults. Gymnasts performed their personalized running approach between 19–25 m to prevent speed from decreasing before touching the springboard/trampette. An Abalakov jump was used instead of counter movement jump (CMJ); it is similar to the CMJ, allowing the gymnasts to freely coordinate the arms and trunk movements to reach maximum height. The Star Excursion Balance Test was exchanged for the Y balance test, as both are valid tests, but the Y test is more practical. It was found reliable when practiced before, and the average of three measured trial counts (Linek et al., 2017).

TeamGym gymnasts scored significantly higher in anthropometry and body composition measurements (Table 7), except for fat percentages, where the difference was insignificant.

In the physical fitness parameters, artistic gymnasts scored higher than TG in hanging pikes, pull-ups, and hip flexibility (Table 8). These findings were in accordance with the nature of WAG and MAG apparatus with numerous hanging events compared to TG with none (FIG, n.d.-b, n.d.-a; Sjöstrand et al., n.d.). TeamGym gymnasts scored higher in grip strength and running speed. The grip strength was consistent with anthropometry, where TeamGym gymnasts are bigger and heavier than artistic gymnasts, and WAG gymnasts are younger than in other disciplines. In gymnastics, the approach run on the vault is not expected to be performed with maximum speed, according to an Artistic gymnastics research on running speed by (Bayraktar et al., 2021). Also, this was noted by Högg & Andersson (2021) that highly experienced TeamGym gymnasts might not benefit entirely from maximal running velocity during the run-up.

The Test of Performance Strategies Questionnaire (TOPS) evaluation was for sub-scales in practice and competition. No differences were found between artistic gymnasts and TeamGym in any sub-scale in the psychological measurements (Table 11). The Sport Mental Toughness Questionnaire (SMTQ) did not differ between disciplines (Table 14). It is commonly believed that mentally tough athletes are more successful (Cowden, 2017) and that there is a relationship between mental toughness and team level (Kristjánsdóttir et al., 2019). As the participants in this current study were all elite athletes, and therefore were not expected to reveal a difference. No difference was found in the Sport Anxiety Scale 2 questionnaire (SAS-2) between disciplines (Table 14).

2.5.4 Differences for the competitive period

The competition period was short because of Covid-19 and lasted four months. It did not show a significant impact on most of the physical measurements.

In the anthropometric and body composition, arm length was significantly longer after the competition period, especially for MAG's measure (Table 15). This is possibly due to a sample size of five where one boy was going through a growth spurt. According to Balyi & Way (2005), peak height velocity in boys is more intense than in girls and, on average, occurs about two years later. Or the differences could be associated with the reliability of the measurements. The muscle mass had increased by 1.28 kg and body weight accordingly, while the fat percentage was slightly less.

Grip strength is less for both left and right arm in the post period. The Y balance test and hips flexibility showed lower values after the competition period (Table 16). These findings are according to training periodization with less emphasis on stretches and basics during the competition period (Bompa, 2009). Behm (2001) reported that static stretching might temporarily decrease the ability to generate power output.

2.6 Limitations

The present study, however, is subject to several limitations. Covid-19 had a significant impact on the measurements. First, many competitions were canceled or moved in 2020, so the national teams were not selected after that season. The participants invited were from last season's national selections resulting in a smaller number of participants and possible lower level of gymnastics. Multiple changes in competition dates resulted in changes in test dates. The pre-and post-competition measurements were supposed to be six months apart but were four months. It would have been beneficial to include evaluation of the level of the gymnast's maturation for the anthropometry and body composition measurements.

2.7 Conclusion

The study aimed to compare physical tests and psychological skills by age, gender, and gymnastics discipline. Also, to identify the main competition period's impact on the physical fitness test. The Icelandic national teams consist of three different disciplines and two different age levels, juniors and seniors. The conclusions were:

- Conclusion 1: Obvious age difference was found in the anthropometric and body composition with seniors scoring higher than juniors in all aspects, but fat percentages.
- Conclusion 2: Physical fitness measurements. In most test events, seniors scored higher than juniors, only in push-ups for WAG and TG juniors scored higher.
- Conclusion 3: When comparing psychological skills for age with the TOPS questionnaire, a difference was found in sub-scales. Seniors scored higher than juniors in activation in practice, and juniors scored higher in imagery in competition. When comparing juniors and seniors with the SMTQ or the SAS-2 questionnaire, no age differences were found.
- Conclusion 4: Gender difference was found in all anthropometric and body composition factors, with males scoring higher than females except for fat percentages, where females had higher percentages than males.
- Conclusion 5: In Physical fitness measurements, males were stronger than females and less flexible.
- Conclusion 6: When comparing psychological skills for gender with the TOPS questionnaire, females scored higher than males in self-talk in practice. Differences were found when comparing the SMTQ questionnaire, where males scored higher than females in the sub-scale for control. A difference was found with the SAS-2 questionnaire, where females scored higher than males in concentration disruption and worry.
- Conclusion 7: There was a difference between disciplines in anthropometric and body composition measurements, with TeamGym gymnasts being taller and heavier than Artistic gymnasts in all aspects but the fat percentage.

- Conclusion 8: Artistic gymnasts scored higher than TeamGym in hanging strength and flexibility in physical fitness measurements, but TeamGym scored higher in grip strength and running speed.
- Conclusion 9: When comparing psychological skills for disciplines with the TOPS questionnaire. TeamGym scored higher than Artistic gymnasts in emotional control in practice. When comparing SMTQ or the SAS-2 questionnaire, no differences were found.
- Conclusion 10: The impact of the four-month competition period was interesting for all disciplines. For the anthropometric and body composition parameters, arm length was recorded significantly more after the competition period, especially with MAG discipline. Grip strength was lower in the post-period measurements. The physical test did not reveal any strength gain during the competition period, but the Y balance test and hip flexibility were less in the post-competition period.

2.8 Futures research lines

Coaches and federations use sport-specific physical tests for their gymnasts to measure, compare, prepare, and motivate. To our knowledge, not many tests are available online with score tables and instructions. In this study, a valid test from the USA (Sleeper et al., 2012, 2016) was modified, and hopefully, further studies will provide the world of gymnastics with effective tests for all disciplines of gymnastics. According to (W. Sands et al., 1991) even the best gymnast can be differentiated by performance in a physical test.

There is considerable interest in targeting psychological skills and strategies likely to differentiate more and less successful athletes. Psychological skills training programs (L. Hardy et al., 2010) should be aimed specifically at women to help them to cope appropriately with high anxiety levels (Kristjánsdóttir et al., 2018; Neil et al., 2006).

2.9 Reference of manuscript

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