ORIGINAL ARTICLE

Technological advances in artistic gymnastics and the impact on its development

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ABSTRACT

This paper looks at the history of technology development in Artistic Gymnastics (AG) by reviewing patent registrations, test procedures for the AG competition equipment by the official control laboratory of the International Federation of Gymnastics (FIG), and major apparatus advances by manufacturers. Equipment became lighter and more resistant with synthetic materials, with a clear tendency to increase elastic (repulsive) capacity. It is noteworthy that the testing laboratory becomes an arbiter for the industry and the FIG when the technological developments and equipment of manufacturers are evaluated for official use. Only 23 companies have equipment approved by the FIG, 12 of them manufacturing AG apparatuses. Suppliers are located in nine different countries (2 in Asia; 4 in Europe; 2 in America; 1 in Oceania). There is still an unequal distribution of access to technologies, which are concentrated in the northern hemisphere. More access to the actual technology is clearly required when we consider that 156 national member federations are affiliated with the FIG as of this writing.

Keywords: Sport history, Sport industry, Sport technology, Patents, Artistic gymnastics.

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INTRODUCTION. THE TECHNOLOGY REVOLUTION ON SPORTS

Technology development has been generating a profound impact on modern society (Jerónimo et al., 2013), including sports (Ullman, 1977). Historical studies investigate how this technological revolution has evolved to the present times (Gross & Roeder, 2022; Vigarello, 1988).

This tendency can be clearly noticed in the specific case of the Artistic Gymnastics (AG) coordinated by the International Gymnastics Federation (FIG) in partnership with a limited number of manufacturers and developers. This process has been guided by the goal of increasing the safety of gymnasts through improved quality, durability and the use of new materials and designs for competitive equipment.

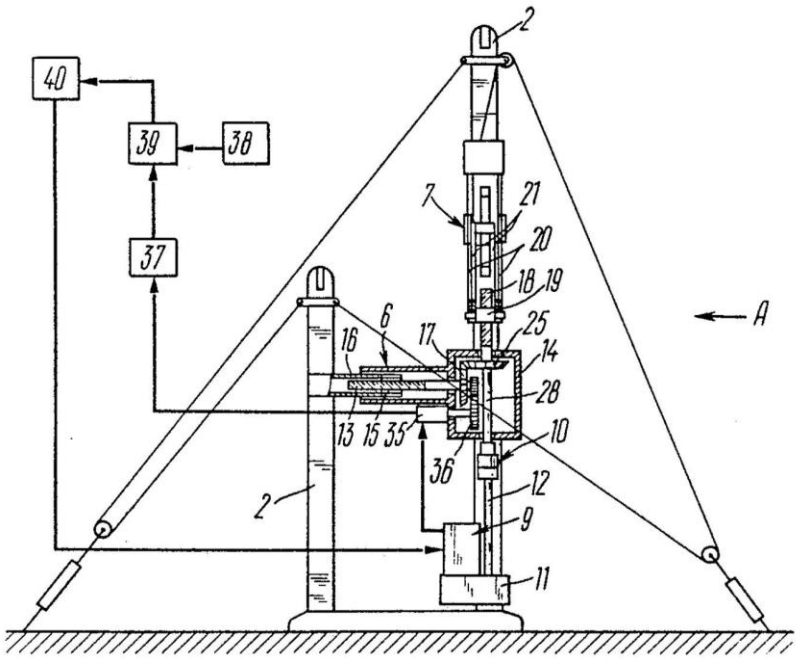
Our study analyses three different categories of source material: 1) apparatus patent registration; 2) the standardisation of test procedures by two official control laboratories of the FIG (GYMLAB in Freiburg and Tokyo Institute of Technology); 3) major apparatus advances from manufacturers that have obtained FIG's certification. A longitudinal study of technical information documented in the AG apparatuses registered Patents was combined with a review of the process of standardized test procedures for the competition equipment in gymnastics, including an analysis of the constitution of the official testing institute GYMLAB for the FIG in the second half of the 20th century as a moderating system for technological development (Fouché, 2017). Some of the main technological advances certified and later officially adopted by the FIG, including the Vaulting Table (VT), the floor exercise system (FX) and the horizontal bar (HB), are studied in more detail as examples of this development. Finally, we examine decades of the official FIG Bulletins to systematize the manufacturers received apparatus approval in order to become potential suppliers for official events observing geographical distribution.

HISTORICAL ANALYSIS OF ARTISTIC GYMNASTICS APPARATUS REGISTERED PATENTS

Technology has become a prominent symbolic, political and economic capital for modern sport, becoming a central aspect of this phenomenon (Bourdieu & Wacquant, 1992). As a catalyst for the sportification process, aspects such as the standardization and certification of equipment and measuring devices used in sports have been consolidated, with particular attention to the high-performance competition context (Fouché, 2017).

The registration of technological advances since the 19th century, through property protection (patents), has become a fundamental device for sports development (Barnett, 2021). Increasingly, patent registration (Figure 1), as part of the process of protecting and dominating the market, was incorporated into sport, becoming an important source for sport history study (Kukkonen, 1998).

Technology development has accompanied the sport throughout modernity, being an important element since the 19th century gymnastics manuals, such as those written by Francisco Amóros y Ondeano (Vázquez, 2006) and even more so as competitive practice expanded in the twentieth century, as seen in the historical records of FIG (Fédération Internationale de Gymnastique (FIG), 2006b, 2006a). This impact of technology on AG was amplified from the second half of the 20th century onwards (Bortoleto, 2018). It is worth noting that this process required the testing, regulation and subsequent certification by FIG for all apparatus, in conformity with the Apparatus Norms (Fédération Internationale de Gymnastique (FIG), 2022a). This process takes many years from the development of the technology to its use in official events.



Source : https://patents.google.com/patent/US4491314. (Retrieved on May 01, 2024).

Figure 1. Uneven Bars. Belyavsky et al. Patent: Jan. 13, 1982 U.S.S.R. 3392651; Jan. 1, 1985 US 4,491,314.

During more than a decade we have investigated hundreds of patents for AG devices, among which we have selected some examples (Table 1), through which we try to analyse the logic of technological development. Other dozens of patents on auxiliary training devices were located (A63B69/0064; US20170296856A1; US20060234833A1, CN204798693U; among others) (Cambia, [s.d.]), however, they were not analysed for the purpose of this article.

Table 1. AG apparatus registered patents*

Title	Patent	Date
Vaulting horse or buck for gymnasiums – Frederick Medart	US 243456A	1881
Portable gymnastic apparatus - Edwin F. Shaw	US 425636A	1890-1907
Vaulting horse – Robert Reach	US 438640A	1890
Gymnastic apparatus - Ira R. Nelson, Frederick W. Lambie	US1503550A	1921
Parallel bar gymnastic apparatus - Nissen Corporation	US 3232609 A	1962
Jumper's landing pit - Jerry W. Sconce	US 3369808 A	1965-67
Roll-fold floor mat for gymnastic and athletic purposes	US 3636576	1972
Resilient floor, especially for gymnasiums	US 3828503 A	1973
Movable support structure for rings gymnastic exercises - Richard Reuther	DE 2330184A1	1973-75
Balance beam with a resilient coating - Richard Reuther	US 3990697A	1975-76
Arrangement for Floor Gymnastics/Floor Panel System	US 4135755	1977
Spring element for gymnastic springboard - Richard Reuther - Spieth Verwaltung	DE 2839477 A1	1978-80
Gymnasium apparatus Uneven Bar supporting - Parry Charles G. & Sherwood David L.	US 4334675A	1979-82
Tumbling floor - John K. Geist - Nissen Corporation	US 4316297 A	1980-82

Springboard Reuther System - Richard Reuther. Tremplin de gymnastique - Sprungbrett zum Turnen.	EP 0086274B1 - DE 2234640 DE A-2329038 DE B-2725401 DE 3203172	1982-84
Suspended uneven parallel bars for competitive women's gymnastics - Frederick H. Lohman	US 4402501 A	1981-93
Vaulting apparatus, especially vaulting horse - Schmalkalden Sport Veb	DE 3426112 A1	1983-85
Gymnastic floor structure having vertical elasticity	US 4648592	1985
Springboard for gymnastics - Otto Benz & Benz Turngeraete	DE 3602784 A1	1985-87
Shock absorbing mounting arrangement for gymnastic rings - Gerald E. Linden	US 4738444 A	1986
Gymnastics bar and method of making the same. - Nichols-Ketchum, M. - American Sports International, Ltd.	US 6475118	1988
Gallows for sport gymnastics with rigid ring suspension - Gérard Barbifieri Henri Miceli - Gymnova	EP 0504235B1 – FR 8916756A – WO 91/08800	1989-91
Gymnastics floor	JP 2535234Y2	1989
Portique de gymnastique sportive a suspension d'anneaux rigides - Gérard Barbifieri & Henri Miceli - Gymnova	FR 8916756A – FR 655551B1	1989-91
Springboard System - Gérard Barbifieri & Henri Miceli - Gymnova	EP 0 572 518 B1 - FR 9102434 – 1991 – WO 1992014516A1	1992-93
Ring frame for hanging the rings for gymnastic exercises - Rolf Daehne - Reuther Turn Und Sportgeraete	DE 4217197C2	1992-94
Parallel bars - Ted Winkel	US 5720697 A	1994
Gymnastic balance beam with articulated beam portions - Gerald J. Lahmann	US 5616102 A	1995-96
Gymnastic apparatus for performing vaulting exercises - Helmut Hödlmoser - Spieth Gymnastic GmbH	EP 0885634A2	1997
Gymnastics springboard with adjustable elasticity designed for training and competition - Gymnova	DE 2103315 A1	2003
Gymnastics springboard - Tremplin de gymnastique réglable en élasticité destiné à l'entraînement et à la competition - Gymnova	EP 1314454 A1 - FR 0115404	2003
Gymnastics floor - Janssen and Fritsen Holding BV - Jacques Marinus Janssen	NL 1026548 A - EP1611930A1	2004-06
Gymnastic equipment - balance beam - Benz Turngeraete - Gotthilf Benz Turngeratefabrik & Co KG GmbH	DE 202005014583U1	2005
Gymnastic floor structure	US 7849646 B2	2007
Air-cushion floor	CN 201099969 Y	2007
Gymnastics springboard with adjustable elasticity designed for training and competition - Gymnova	US 7175567 B2	2007
Flexible mat with multiple foam layers	US 20130017372 A	2011
Pommel horse training device for group gymnastics	CN 213724601U	2020-21
Gallows for sport gymnastics with rigid ring suspension	RU 2021128666U	2021

**EP – European patent; DE – German patent; RU – Russian patent; CN – China patent; US United States of America patent; NL – Nederland patent; FR – France patent; JP – Japan patent; WO – World Intellectual Property Organization.*

It is possible to say that the engineering of gymnastic equipment was, initially, based on the use of natural materials, such as wood and leather, combined with metallic alloys, such as iron. In the second half of the 20th century, new compounds, such as stainless steel, aluminium, fibreglass and other synthetic materials such as Fibre-Reinforced Polypropylene (FRPP), fibre leather and carbon fibre, began to be used in the

construction of equipment, such as we see in the Uneven Bars' (UB) technical description of a recent model from the GYMNOVA brand (Ref. 3265) (Gymnova, 2014):

> *Round fibreglass handrail covered with natural fibre.*
> *This material, which is more malleable than wood, allows for a more homogeneous coating, which increases the hand-rails lifespan.*
> *The texture provides an efficient grip with less time required to prepare the bar, as these handrails need much less chalk during use.*
> *The handrails show no wear even after several routines and therefore provide better protection for the gymnasts hands, thus enabling high quality routines. They can be safely cleaned with water.*

This trend is corroborated by the recent study of the development of HB (Kaimakamis et al., 2018), as well as by the analysis of the evolution of the Ring Frame for men's AG (US425636A 1980; DE2330184A1– 1973; RU2021128666U – 2021). The emergence of the logic of efficiency is remarkable, a feature pointed out by Jacques Ellul (Jerónimo et al., 2013) and which gives a meaning beyond the technical-practical functionality of the apparatus (Slater & Barry, 2005).

Most patents aim to "*optimize the gymnast's performance*" (Middelkoop & Stone, 2019) and, at the same time, develop safer equipment, as we see in excerpts like these: "*The object of the present invention is to improve the safety of gymnastic equipment used to support one or more raised exercise bars [...]*" (US4334675A); "*The Invention has for its object to improve the safety of gymnastic equipment [...]*" (DE202005014583U1). The advancement of technology was also accompanied by studies that suggested a direct relationship between them and some recurrent injuries (Armstrong & Relph, 2021).

The design of AG equipment was gradually resulted in lighter structures, easier to install and transport and with greater durability (Oliveira et al., 2023). The technological modifications of springboards represent a good example of the important change in the design of the apparatus, drastically modifying the impulse that gymnasts can achieve, as shown by several studies (Coventry et al., 2006; Cuk et al., 2011; Lehmann et al., 2020; Yeadon et al., 2006; Zanevskyy & Zanevska, 2023). The "*protection*" of gymnasts is constantly mentioned in the technical arguments presented in patent applications.

The importance of safety in gymnastics equipment development is particularly evident with the introduction of the vaulting able (EP 0 572 518 B1), promoting a disruptive change in technology, when compared to the previous model (vaulting horse) patented at the end of the 19th century (US 243456A; US 438640A) (Table 1).

The Vaulting Table was officially used by the FIG for the first time in 2001 in Ghent (Belgium) at the FIG World Championships. The main intention was to significantly improve safety compared to the previously used vaulting horse (VH). Accidents on the VH, like what happened to the Chinese Gymnast Sang Lan in 1998[1] (Los Angeles Times, 1998), were crucial in accelerating this development. Developers and biomechanics principles contributed to the development of a new Vaulting Table (VT), one of the most representative technological modifications observed in modern AG (Schärer et al., 2019).

[1]*Several other accidents, like the ones with the American gymnasts Brian Meeker (1981) and Trend Dimas at US National Championships, were widely reported in the media. Other issues with the AG apparatus that resulted in accidents like Tyler Williamson's when the Rings broke during his routine at the Men's NCAA Gymnastics Championships, certainly reinforced discussions about the apparatus safety. (Source: USGF Gymnastics Magazine, Sept./Oct. US Gymnastics Federation, Fort Worth -TX, 1981).*

Concomitantly, a greater capacity to absorb the impact is highlighted in the patents, seeking to minimize the effects of intense and prolonged training that is required to achieve high performance in AG.

> *"The object of the present invention is to provide a gymnastic floor whose resilient and damping properties are relatively constant across the diagonals of the gymnastic floor" (NL1026548C2);*
> *"The present invention is to provide a gymnastic floor capable of easily changing a repulsive force according to a use and an actor." (JP2535234Y2).*

It is clear that equipment has modified with more malleable and resilient materials[2] (Oliveira & Bortoleto, 2011). These aspects are often mentioned in the sport's most important technical document, the FIG Apparatus Norms (Fédération Internationale de Gymnastique (FIG), 2022a). For example from parallel bars (PB): "*The bars must have elasticity; 3.2. To assure the efficiency of this elasticity the fixing points of the bars on the uprights must be articulated*" (Fédération Internationale de Gymnastique (FIG), 2022c, 2022d); and from horizontal bar (HB): "*3. Functional properties: 3.1. The horizontal bar must be elastic and be secured against breaking through; 3.2. The elasticity is not just determined by the bar but also by the apparatus, acting as a whole*" (Fédération Internationale de Gymnastique (FIG), 2022d).

Innovative scientific advances from engineering to work safety were incorporated, including metal alloys for the bar used in HB or fiberglass in UB (Pekkeriet, 2017). The evolution of biomechanics (Yeadon et al., 2012) and much other scientific evidence, contributed to the improvement of official equipment used in competitions and to the development of numerous training devices. The catalogues of the main specialized companies show hundreds of technological innovations.

The protection of technology commercial rights through patent registration requires significant financial resources, and it has become necessary for technology protection before its regular diffusion/use (Barnett, 2021). Thus, registration has been carried out by the private sector, by a small number of inventors, mostly linked to companies already consolidated in the field of gymnastics. In the case of gymnastics, the application of the patents shows an initial dispute between European and North American engineers and developers, connected to a small group of corporations (manufactures). The patent requests are usually made in the country of origin of the inventors or companies responsible for the technology. After the second half of the 20th century, multiple applications became common in order to guarantee the privilege of the international market (example: FR 9102434 in 1991 and EP 0 572 518 B1 in 1992). Patents were most frequently required in the USA and Germany in the 19th century, and in other countries throughout the 20th century (France, Holland, Japan, Russia and Australia). The participation of China has grown notably in the beginning of the 21st century, revealing a more competitive industry and different market distribution.

The development of new technologies and the registration of the commercial exploitation copyright (patent) was sufficient for companies in the sector until the mid-1980s, when the FIG began to require the certification

[2]*The term 'elastic technologies adapted to humans' for gymnastics apparatuses or parts thereof is used in this article more comprehensively than could be derived from a purely mechanical definition of 'elasticity': Here, 'elastic construction' for gymnastics apparatuses refers to structural optimizations with regard to the following 4 aspects: a) In accordance with the design specifications of the gymnastics apparatus (e.g. height of the springboard), the greatest possible unobstructed path of movement is available in the contact phase with the athlete for compression and the subsequent decompression; b) In the decompression phase of the gymnastics apparatus, as much mechanical impulse as possible is returned to the gymnast from the impact introduced by the athlete during compression; c) Moving parts of the 'elastic construction' include as little mechanical mass as possible to minimize peak forces; and d) The gymnastics apparatus has an adapted oscillation behavior of the elastic components in relation to the biomechanical requirements of the gymnast.*

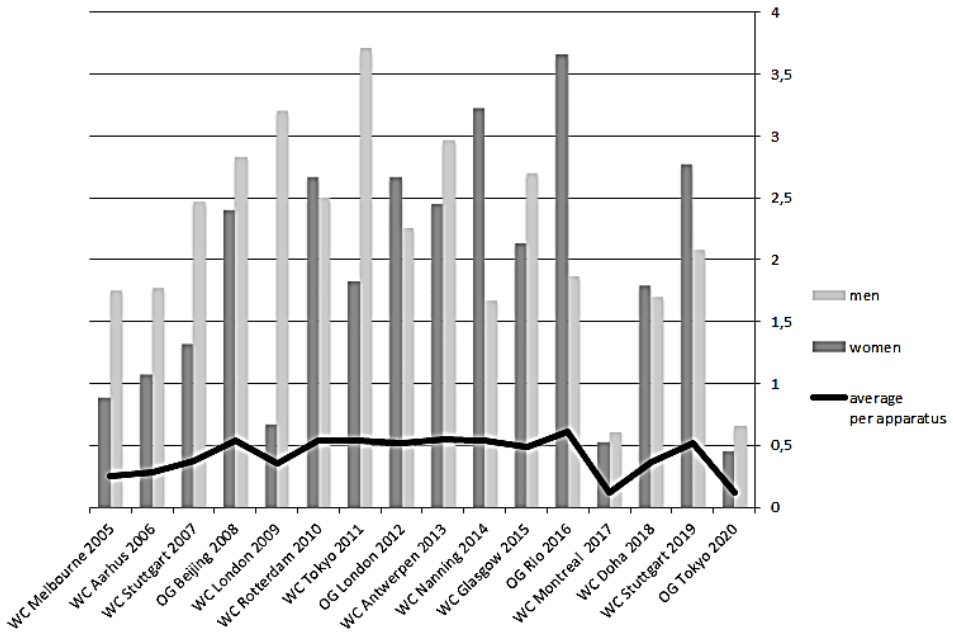
of equipment for use in official events.

STANDARDISATION OF THE TEST PROCEDURES FOR COMPETITION EQUIPMENT IN GYMNASTICS

The FIG has published norm-requirements for gymnastics equipment for more than 60 years (Fédération Internationale de Gymnastique (FIG), 1960). Since 1984 the FIG has officially relied on the expertise and assistance of specialized testing institutes for the development, verification, and control of these standards. The reasons for these measures:

a) To guarantee a certain safety standard for gymnastics equipment in view of the athlete's health.
b) Useful and necessary aid for insurance and legal questions after a serious accident with recourse claims by the athletes.
c) To ensure equal opportunities for all athletes.
d) Objective admission procedure for gymnastic equipment.
e) To prevent undesired or uncontrolled changes in the character and the contents of the exercises.

The performance level of the world's elite AG gymnasts has always been evolving (Fédération Internationale de Gymnastique (FIG), 2000). Some of the most difficult skills were not even thought possible by outside experts before the first performance at a competition. In addition to the individual difficulty, the accumulation and density of such skills within one single exercise has increased enormously in recent years (Ferreirinha et al., 2009). This has also increased the risk of injury due to a fall or repeated high mechanical impacts during training. The FIG feels responsible for guaranteeing a certain safety standard for gymnasts using official gymnastics equipment. Therefore, properly designed standardisation tests for the gymnastics equipment are a central building block in this endeavour. This does not only result from the obvious moral obligation towards the competitors, but also from financial and legal positions towards insurance companies, which in the case of a catastrophic accident, would quickly have immense financial claims at hand.



Source: Non-published internal Database GYMLAB 2021.

Figure 2. Difference in Results of All Around Finals between 1st and 4th place in FIG Competitions of Artistic Gymnastics. The black line indicates the average difference between first and fourth place per apparatus.

An analysis of the "*All Around Finals*" at the most important FIG competitions of the last 16 years shows the average difference between first and fourth place for individual apparatus, was 0.5 points or less (Figure 2).

Such a small difference of 0,5 points already corresponds to the point deduction to be made according to the current evaluation guidelines for "*any major or severe deviation from the perfect end position and from perfect technical execution or for any major or severe adjustments to hand, foot, or body position*" (Fédération Internationale de Gymnastique (FIG), 2022g, 2022h). In this context, just imagine a gymnast who practices his vault in his national training centre in preparation for upcoming Olympic Games on another continent. He might use a vaulting board which was produced in a company of his home country and with elastic properties completely different from those used during the competition. This athlete would clearly be at a disadvantage, as she/he would not be able to practice with the competition vaulting board. Standardisation testing, therefore, should guarantee the existence of only a limited bandwidth in the differences of functional properties of all official gymnastic equipment. Therefore, certified equipment is an essential component to ensure safety and equal opportunities for all athletes.

The market for gymnastic equipment, although small, is extremely competitive in some countries. Exactly defined norm test procedures make the work for the FIG easier when approving gymnastics equipment for international competitions. When norm tests are carried out by a neutral institute, independent of companies or national federations, an objective admission procedure can be ensured.

The development of gymnastics skills has always been influenced by the development of gymnastics equipment (Sands et al., 2003). This can easily be seen, for example, in the technical development of the vault having relevant improvements introduced already between 1940 and 1980. During these years, Richard Reuther and Rolf Daehne in Germany developed the "*Reuther board*" (i.e. EP 0086274B1) (Daehne, 1975), which was well known worldwide to all gymnasts in those days (Figure 3) (Göhler & Spieth, 1989). Only these improvements of the gymnastics apparatus made the most difficult vaults at that time possible.

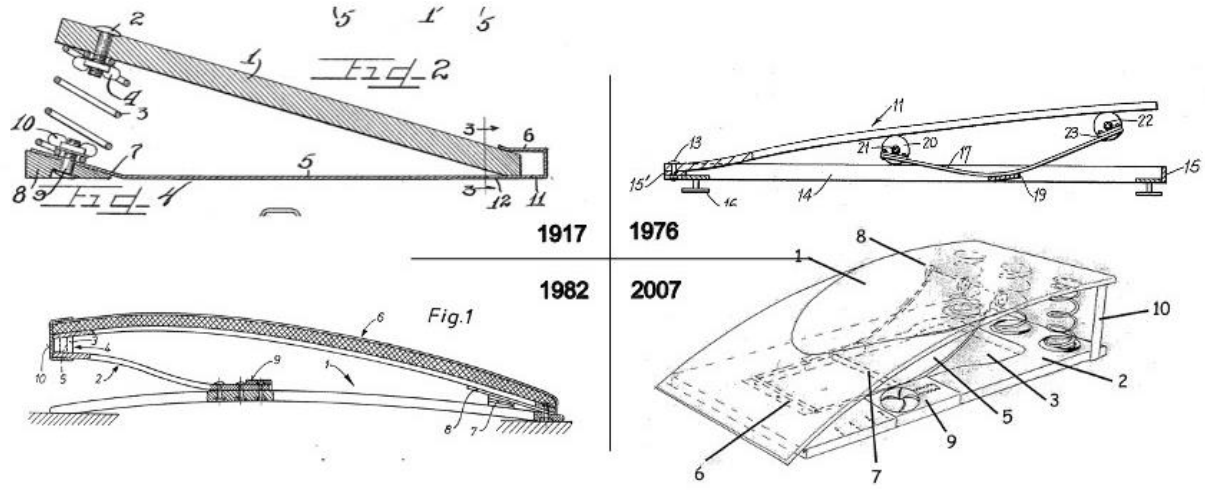


Figure 3. Springboard patents.

In recent times, new materials and components in gymnastics equipment have resulted in skills being possible only because of these changes. The FIG can fulfil its responsibility with regard to desired development tendencies only, when control is kept on such changes. Standardisation tests can help the FIG in preventing undesired or uncontrolled changes in the character and the contents of the exercises.

THE EMERGENCE OF THE OFFICIAL TESTING INSTITUTE GYMLAB

In recognition of the reasons above, the FIG sought contact with the Institute for Sport and Sports Sciences at the University of Freiburg in Germany in 1984. As a consequence of first cooperative projects and the constantly growing requirements and experiences an official testing institute (GYMLAB) was founded at the University of Freiburg.

Up to 1985, the FIG standards only contained specifications on the shape and dimensions of the gymnastics equipment. At major competitions, objection procedures from the delegations were initiated about the competition equipment and led to internal discussion within the FIG. It was obvious that the high importance of the biomechanical interactions between gymnastics apparatus and athletes had to be reflected for an improvement of the apparatus norms. As a basis, the biomechanical interaction between the athlete and the gymnastics equipment was scientifically researched for all competition equipment using classical biomechanical methods (3D-Kinematography, 3D-Dynamography, Electromyography, etc.). Depending on the problem, measurement projects were carried out in the laboratory, training halls and at major competitions. Based on these measurement results and considering many practical and sport-specific requirements, suitable standardisation test procedures were developed. Depending on the gymnastics equipment, so-called "*artificial athletes*" have been developed that can simulate the central dynamic effects on the gymnastics equipment (mechanical deflections and impacts) and can be used repeatedly for standard tests under constant conditions (Figure 4).

Source: GYMLAB.

Figure 4. FIG Testing Device for landing mats. Low-friction guided drop mass for standardised impact tests on landing mats. Electronic sensors record mechanical parameters such as braking forces, deformations, rebound height.

The improvement and adaptation to new requirements for the equipment tests is always an ongoing process. A central task for the GYMLAB is therefore the development and improvement of standardisation tests for competition equipment of the International Gymnastics Federation. After periodic revisions by a "*FIG Apparatus Commission*", the current apparatus specifications and, above all, the newly developed mechanical test procedures were precisely described and published at the Apparatus Norms:

> *The purpose of these Apparatus Norms is first, to have equivalent apparatus at all competitions. It is essential for the competitors to have the same, optimal conditions for the preparations for competitions and at competitions all over the World. This is necessary for practical reasons, for competition fairness and comparison and for safety. All apparatus used at official FIG events; the Olympic Games and the World Games must have a valid FIG Certificate. This Certificate will be issued by the FIG, provided the apparatus has been tested successfully (Fédération Internationale de Gymnastique (FIG), 2022a).*

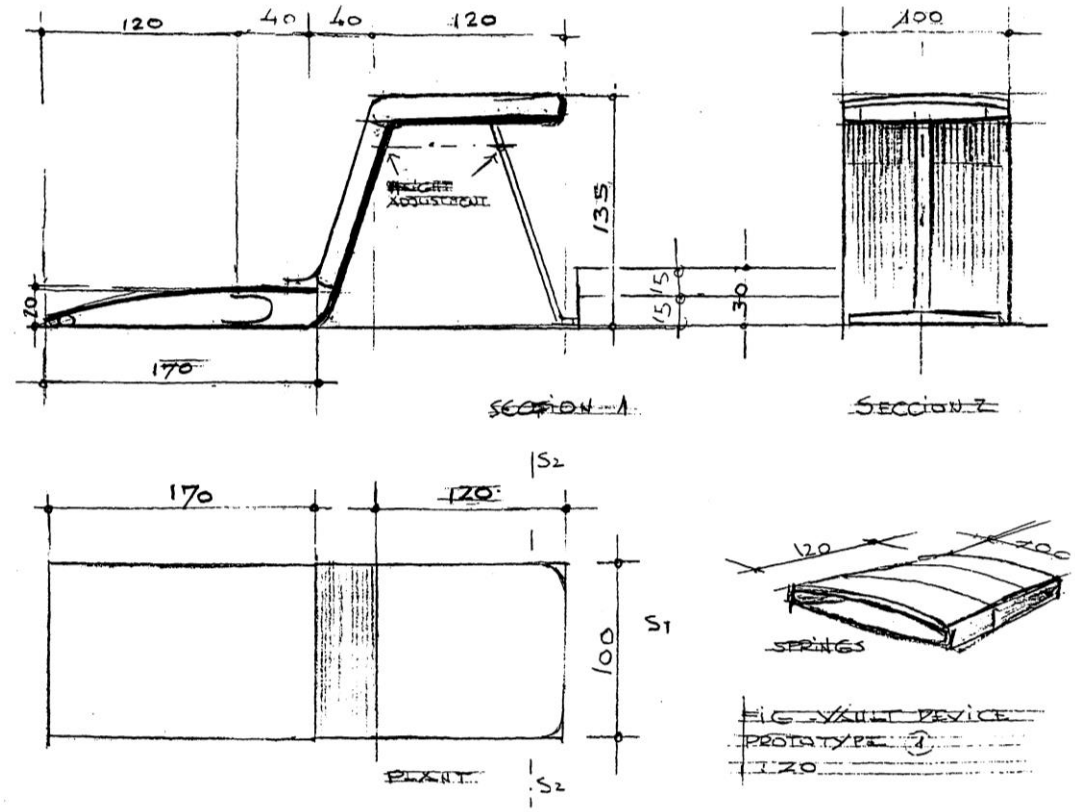
GYMLAB and another testing laboratory at the Tokyo Institute of Technology (TIT) have taken on the task of testing prototypes for all equipment used in international competitions according to the standardised procedures (Fédération Internationale de Gymnastique (FIG), 2022e). These tests are an integral part of an equipment approval system for FIG competitions: The authorised FIG bodies will only approve the equipment for use after the company has submitted an official application and two steps were successfully passed. First a positive result with all specified mechanical tests at one of the two official institutes and second a practical gymnastics test at a training centre which must be specified by the FIG. The first procedure must be repeated after a specified period, even if the company states that no change has been made in the manufacture of the equipment. The list of all gymnastics equipment currently approved for FIG competitions is published periodically by the FIG. In a database with individual access rights, equipment manufacturers, organisers of competitions, judges and interested parties can inform themselves about the status of an approval procedure.

To ensure that the extensive regulations regarding the apparatus at the competition site all comply with the specifications, the area of responsibility of a "*FIG Apparatus Commissioner*" was defined. At all World Championships and Olympic Games, a representative of the GYMLAB is usually entrusted with supporting the responsible authorities of the FIG (Technical Commission presidents - TCP) via defined checklists. A competition inspection of the equipment at the major events must also include that the equipment on site corresponds exactly to the prototypes submitted for the laboratory tests, according to the FIG regulations (Fédération Internationale de Gymnastique (FIG), 2022b).

Beyond these defined tasks for GYMLAB, the many experiences gained in connection with gymnastics equipment issues led to more and more requests for advising the FIG Committees on biomechanical issues relating to gymnastics equipment. One of the most outstanding examples of this is the introduction of the Vaulting Table around the year 2000 (Schärer et al., 2019). GYMLAB was heavily involved in the introduction of this completely new device from the very beginning: The disadvantages of the vaulting horse used until then were becoming more and more obvious to the FIG. Based on several biomechanical safety-related and practical requirements, the FIG with the full support of its vice-president at the time, the Brazilian Mr. Siegfried Fischer, called on the industry to develop an improved solution for the vault in the early 1990s (Figure 5).

Three different prototypes were selected to be tested in training in selected international training centres supported by biomechanical measurements. Following these preparatory steps, the Vaulting Table could be introduced at the World Championships 2001 in Ghent (Belgium) after prior determination of dimensions and standard test procedures. Looking back at the successive versions of the FIG norms from then until the

current edition (August 2022), it can be seen that the standards of the functional characteristics for the Vaulting Table established before the 2001 World Championships have been maintained without significant adjustments (Spieth Gymnastics, [s.d.]).



Source: Family collection. Cordially shared by Mr. Erlo Fischer.

Figure 5. Proposal for a Prototype of a Vaulting Table (1995) by Siegfried Fischer, presented during a Gymnastics Apparatus Manufacturers Meeting in Munich in 1995.

Apart from the VT just mentioned several improvements have been introduced to the AG equipment in the last decades. Some changes have been made to the internal structure, unrecognisable to a layperson from the external appearance. These improvements have had a significant impact on gymnastics and are largely thanks to the equipment manufacturers, dedicated coaches, the apparatus commission and the two testing laboratories coordinated by the International Gymnastics Federation. Based on that we agree with Vigarello when saying:

> *Les opérations corporelles changent avec les modifications de leurs conditions spatiales ou instrumentales. Impossible de les étudier sans évoquer leur solidarité avec chaque élément de leur environnement. Une réciprocité ente les mouvements et les objets qui les portent ou avec ceux qu'ils animent. Une technique corporelle qui est aussi bien l'écho, le reflet, que l'activation de tels objets (Vigarello, 1988).*

Considering only the companies (12 in 2012 and 13 in 2022) with equipment approved by the FIG (Table 2), the AG equipment market is centralized in nine different countries, located 2 in Asia, 4 in Europe, 2 in America

(North) and 1 in Oceania.

Table 2. FIG recognized suppliers (2012-2022).

Manufacturer	Country	2012	AG Apparatus	2022	AG Apparatus
AMERICAN ATHLETIC, INC. AAI	USA	Yes	FX, BB, PB, HB, UB, RF, VT, PH	Yes	FX, PH, RF, VT, PB, HB, VB, UB, BB;
BAENFER GmbH	Germany	Yes	FX, VT, UB, RF	Yes	FX, PH, PB, BB, RF
CHUNHE ATHLETIC GOODS CO., LTD	China	No		Yes	FX, PH, PB, UB, BB, RF
GYMNOVA	France	Yes	FX, HB, PH, VT, PB, BB, UB	Yes	FX, PH, RF, PB, VT, HB, VB, UB, BB
SA SPIETH AMERICA	Germany - Canada	No		Yes	FX, PH, VT, HB, VB, UB, BB, RF
SPIETH GYMNASTICS GmbH	Germany	Yes	FX, VT, HB, BB, UB, RF, PH, PB	Yes	FX, VT, PB, HB, RF, UB, BB, PH
SENOH CORPORATION	Japan	Yes	FX, VT, VB, PH, RF, PB, HB	Yes	FX, PH, VT, PB, H, UB, BB, RF
SHANDONG CANNICE SPORTS (France corporation ABEO Group; German incorporation ERHARD Sport)	China	Yes	FX, RF, VT, BB, UB, HB, PB	Yes	FX, PH, VT, PB, HB, UB, BB, RF
SHANDONG TAISHAN SPORTS EQUIPMENT Co., Ltd.	China	No		Yes	FX, PH, VT, PB, HB, VB, UB, BB
ZHEJIANG SPORTING GOODS CO., LTD., (GAOFEI BRAND)	China	Yes	FX	Yes	FX, PH, VT, PB, HB, RF, UB, BB
ACROMAT	Australia	Yes	VT, PB, FX	Yes	PH, HB, BB, RF
CONTINENTAL SPORTS LTD.	UK	Yes	FX, PH, RF, HB, UB, PB, BB	Yes	PH, PB, HB, UB, RF, BB
NOVAN SPORT	France	Yes	RF, VT	No	
JENSEN	Netherland	Yes	FX, PHVT, PB, HB, UB, BB, RF	No	
SA SPORT	Canada	Yes	VT, RF, PB, FX	No	
PIGNATTI & CO. S.R.L	Italy	No		Yes	FX

Source: Prepared by the authors based on data available on the following websites: https://www.gymnastics.sport/site/apparatus/app_view.php and https://www.gymnastics.sport/site/pages/bulletins.php (Retrieved on May 01, 2024).

These data show a dynamic market, with the emergence of new companies, the merger of some of them, and the departure of some from the sector, with a clear rise of devices certified by Chinese suppliers. This condition, according to Sterling & McDonald (2020), contributes to changes in the sports technology access and, gradually, in development conditions in different regions and countries.

In September 2023, the new GYMLAB headquarters was inaugurated in Teningen (Germany), with a clear signal from FIG to maintain collaboration with the laboratory in search of improving the certification processes mentioned above (FIG News, 2023).

CONCLUSIONS

All the official AG apparatuses incorporate technological advances by the use of non-natural materials, with

a modern architecture and renewed layout including diverse colours and adornments. Equipment became lighter and more resistant with synthetic materials, with a clear tendency to increase elastic (repulsive) capacity. Through a slow but constant historical process, including the technological advances in patent registrations and in the certification (approval) process of the laboratories accredited to the FIG, a safer sport has evolved.

It is also noteworthy that the testing laboratory becomes an arbiter for the industry and the FIG when the technological developments and equipment of manufacturers are evaluated for official use. It is possible to note, therefore, the centrality of the FIG in the governance and development of AG, as already indicated by other studies (Cervin et al., 2017).

Our findings demonstrate that technological development modulates the training and competition process in gymnastics and produces changes in the rules (Code of Points - CoP) of AG. These advances are influenced by the culture of gymnastics, modifying it reciprocally. We argue that the evolution of technology favours the development of a more acrobatic sport based in the incremental use of sophisticated "*elastic*" technologies. These innovations facilitate the development of more complex gymnastics skills that are regularly incorporated in the CoP. Therefore, coaches need to be aware of new equipment to optimize training and increase the safety of all gymnasts considering the long-term process (Bortoleto, 2018). Thus, the technological regulation, through the standardization and certification of apparatus, adds a relevant normative layer to the practice of GA, adding to the layer strictly delimited in the Code of Points for gymnastics skills. A double notarization that makes the sport even more controlled and expressive and constituting, in a simplistic allusion to Thomas Kuhn's concept of paradigm, a new paradigm for this sport. In fact, both layers required many decades for their conception and implementation and are still undergoing constant improvements, showing that there is a dynamic that requires constant monitoring and discussion.

There is still an unequal distribution of access to technologies, which are concentrated in the northern hemisphere of the globe. Africa, Central and South America, for example, have no suppliers recognised by the FIG. Thus, important economic sources guide gymnastics tech access and leads to the sport's unequal development. This scenario reinforces the current hegemony of some countries as evidenced by numerous historical studies, which reveal the urgent need for more equitable representation and inclusion of other countries in the global effort to refine and better distribute technological advances. A more balanced development and distribution is clearly required when we consider that more than 156 national member federations are affiliated with the FIG as of this writing (Fédération Internationale de Gymnastique (FIG), 2022a). In fact, the FIG, recognising this historical problem, has been developing an equipment donation program for developing countries since 2016 (Fédération Internationale de Gymnastique (FIG), 2022f).

Although patent registrations show a constant technological innovation since the 20th century, accentuated in the last decades, we also note that it is necessary to validate them so that the equipment can be used in official FIG events. In this way, the certification process acquires a prominent role. There has been a notable increase in FIG certification requests. The international market has been guided by the FIG Apparatus Norms which in the past was a simple certification, but now is a sophisticated, extensive and standardisation test process at the official testing laboratories. The rise of companies with many certified AG apparatus has further increased the competition to become official suppliers of international events, especially the World Championships and Olympic Games. At the Rio de Janeiro Olympic Games in 2016, two traditionally competing companies (GYMNOVA and SPIETH) (Janssen-Fritsen, 2014) came together in a *consortium* as official suppliers. It is evident, as mentioned before, that there is a clear challenge to improve the equipment distribution, making it possible worldwide, as well as reducing costs for greater accessibility.

The standardisation of AG equipment, through the approval of laboratories and testing processes seems to be reducing the differences in equipment and, as a consequence, to be facilitating the adaptation of gymnasts who participate in different competitive events. This process was built under the argument of offering greater safety to athletes.

Finally, we understand that different changes on apparatus have not yet been integrated into the certified equipment, showing that the history of technological development is ongoing.

AUTHOR CONTRIBUTIONS

The article was written by both authors in its entirety. The empirical data (historical analysis of patents and equipment providers) was carried out by the first author; while the analysis of GYMLAB historical documents by the second author.

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