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Review Article

Anthropometric Determinants of Competitive Performance in Gymnastics: A Systematic Review

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ABSTRACT

Background: Gymnastics is a highly skilled, complex artistic and aesthetic sport with a specific training process and which demands high levels of physical and psychological stress in competition. Not many studies explain a good proposal which determinate the role of anthropometric traits to competitive performance. In this view, based on a critical examination of the literature about "Anthropometric characteristics" and "Gymnasts performance", the aim of this research is to identify the anthropometric factors that have been studied to predict a higher performance in Gymnastics.
Materials and Methods: Google Scholar, Springer, PubMed, Europe PMC and Google databases EBSCO were explored till May 2019. Studies published in English language were included. Several anthropometric parameters affecting the performance in rhythmic, acrobatic and artistic gymnastics were considered in this study. Out of total 76 studies reviewed, 16 studies met our inclusion criteria.
Results: Various anthropometric characteristics such as body size and composition affect the functional parameters (physical capacity), fitness (explosive strength, maximum speed, anaerobic and aerobic capacity) and agility that will benefit positively in enhancing the performance in gymnastics.
Conclusion: Based on the findings of the present study it is considered that requisites for the success of gymnasts depends largely on their physical characteristics, namely somatic dimensions, somatotype and body composition. Gymnast's anthropometric traits have been linked to performance scores in all apparatuses suggesting marked influence on overall presentation and final standing.

Key words: Back strength, Anthropometric variables, Performance, Gymnasts.

INTRODUCTION

Gymnastics is a skillful sport which was developed under a philosophic idea *'Menssana in corporesano'* which supposes a harmonized body and soul. [1] Gymnastics involves the exercises that demands strength, flexibility, balance, agility, endurance and control. [2] This discipline has a long tradition with the International Gymnastics Federation (FIG) being founded in 1881(FIG, 1981). [3] The word draws the meaning of 'to train naked', 'train in gymnastic exercise' and generally 'to train, to exercise'. [4] Competitive artistic gymnastics is the best known of the gymnastics events. It includes the four

women's events (vault, uneven bars, balance beam and floor exercise) and six male's events (floor exercise, pommel horse, still rings, vault, parallel bars and horizontal bar). [5] Gymnastics is one of the hardest games, which has interwined science and technology to improve the performance of the athletes. The scientific principles and concepts like 'Therblings' require not only innate amounts of strength, but also grace, flexibility, endurance, balance, speed, control and focus. [6]

Gymnastics is a highly challenging and demanding sport calling for a complex set of favorable traits for obtaining competitive success. Moreover it was stated that a successful gymnasts should be competent in terms of motor skills, coordination, body size and shape. It has been emphasized that the prerequisites for the success of sport depends largely on their physical characteristics, namely somatic dimensions, somatotype and body composition. [7]

Anthropometrical assessment helps to improve the understanding of gross functioning of the human body by measurement of body's size, shape, proportions and compositions using non-invasive, affordable and portable devices. [8-10] Anthropometric measurements have traditionally been used in the identification of young talented female gymnasts. [11] The central interest of anthropometry is that of physical performance in particular, but not limited to sport performance. [12-13]

Throughout the development of the game of gymnastics, the moves and the demands of the competition have increased a great deal. The most important step in gymnastics development was the change of apparatus constructions, which are now highly pre-tensed and elastic. [14-16] Today professionals believe that the hours of training have tripled from 2 hour training a day in the 30s to 5-6 hours in the modern times. Also studies reported that gymnasts train 1500 hours per year as a result of this from year 1993 till 2000 it was observed that several physical morphological variations exist. [17] Because of the emergence of complex technical skills and its association with body characteristics in gymnastics importance is now drawn to predict the differences on the success and identification of young talented gymnasts. In general, we did not find a complete proposal which could identify the relationship of variations and determinants of a competitive sport performance among rhythmic, acrobatic and artistic gymnasts. That is why the aim of this research was to establish, through a critical examination of the literature about the anthropometric factors that have been studied to predict a higher performance in Gymnastics.

METHODS

This systematic review included the data available without any limitation from the following databases; Google Scholar, Springer, PubMed, Europe PMC and research databases

Search Strategy:

The search was done by using the key words: gymnasts, anthropometric profiles, somatic constitution, body composition, morphological models, growth and pubertal development, performance characteristics, level of performance.

Inclusion Criteria:

Studies with the following criteria were included: anthropometric values, profile or characteristics and somatic constitution, body composition, somatotypes and morphological models, growth and pubertal development to determine the elements of the performance, factors influencing performance and the level of the performance (reliability), and being published in English language. The studies involving the parameters other than anthropometric were excluded.

RESULTS

Description of studies:

Seventy six studies were identified and on the basis of inclusion criteria 60

studies were excluded and only 16 studies were included in this study. [7-8,18-31] A total of 1257 gymnasts participated in these studies. Both males and females were included in 7 studies, [18,21,24,25,26,28,31] only male gymnasts in three studies [8, 22, 30] and in six studies [7,19-20,23, 27,29] only female participants were enrolled. Out of the total 1257 gymnasts included in these studies, Rhythmic gymnasts:300, acrobatic gymnasts: 300and Artistic gymnasts: 657 had participated. The mean age of the gymnasts participated in these studies are from 7 to 27 years. Full details of each study are provided in Table 1.

studies included in critical literature when assessed have anthropometry as a primary component. However, we studied the relationships of the anthropometric factor with other secondary factors included in these 16 studies. It is here noteworthy to state that these secondary parameters accompany the anthropometric traits to frame a suitable design on to the part of the coaches as well, as sports expert to design unique training protocol depending on the individual characteristics. This will assist the athlete to acquire demand depending training which ultimately leads one to competitive success. The associations of these secondary factors were studied along with the primary factor and are explained as:

Relationship of anthropometric and technical determinants on the gymnastic performance

The anthropometric traits were assessed in relation to the technical elements in seven studies where relation of these factors was studied among rhythmic gymnasts in six studies [18, 20, 24- 25, 26, 28] and in artistic gymnasts [23] in one study. It was observed that a multiple anthropometric traits and a technical development program aids in the success of competitive gymnastics events. Furthermore, it was concluded from the studies that successful performance in gymnastics requires multiple years of practice and training that begins from early age of 6 years and continues until adolescence. Task duration and structure along with physical traits are crucial characteristics influencing the process. [18,20]

Relationship of anthropometric factors, psychological factors and the training process contributing the success.

Three studies [24- 25, 27] evaluated the positive relation of anthropometric traits along with mental training and technique process contributing to the success of gymnasts. It was stated that the efficacy of athlete's sport performance depends on the targeted training in certain periods, organization, management, individual adaptation of an athlete to the loads of training and competitions. [32-34] If the requirements of athlete training are followed, there are premises for their successful participation in the most important international competitions.

DISCUSSION

The objective of this study was to review the literature considering the role of anthropometric characteristics in the contribution of performance in gymnastics. In this review only 16 studies [7-8, 18-31] of the rhythmic, artistic and acrobatic gymnasts were included and their results were classified into three categories. This review showed that anthropometric values are helpful to understand clearly the specific performance requirements which later assist the coaches as well as the professionals to train the gymnasts accordingly so that they can contribute the maximum in the competitive events.

Anthropometry and performance

The appearance and aesthetic standards of body shape entail a better execution of gymnastics movements. Besides skills, training, motivation, psychological factors, physiological and biomechanical demands, numerous anthropometric compositions such as body size, body shape, and body type are responsible to contribute for the

improvement of the performance of an athlete. [8, 20] Age, height, body weight, BMI, circumferences, girths, skin folds, somatotypes, fat percentage, lean body mass, body composition etc. were evaluated in all the 16 studies [7-8, 18-31] mentioned in the table 1. The contribution of the age, height, body mass, circumferences and diameters however showed a significant result in all the rthymic, acrobatic and aesthetic gymnasts. Gymnasts while in their developmental period induce training stresses on the cardiovascular and musculoskeletal system which involves changes in their body size and physiological characteristics side by side. [35] Because skeletal maturity during growth is reasonably well correlated with height, weight and other indices of physical development, [27] rthymic gymnasts athletes have broader shoulders, narrow hips, long and slim upper and lower limbs, very low body fat and show symmetrical values in the sitting and standing height ratio. [35-36] Such observations were found in studies. [18-20, 24-25,28] Low body mass appears to be an obvious benefit when performing skills that require movement with intricate routines. [37]

Somatotype and Performance

The somatotype of all acrobatic gymnasts is distinguished by predominance of the mesomorphic component in all event categories, which is in line with findings presented by Taboada-Iglesias et al. [31] who indicated mesomorphy in both tops and bases being one of the few variables that were not significantly different between particular roles. This is similar to the data provided by Bester and Coetzee [38] who showed that high values in mesomorphy in female artistic Gymnastics gave the best results in competition. Another study performed by Classens [7] suggested endomorphy as an indicator of performance in elite gymnasts. Bester and Coetzee [39] suggested ectomorphy as an indicator of athletic talent in gymnastics. The mesomorph and ectomorph components being predominant in rhythmic gymnastics. [40-41]

Motor ability

The psychomotor speed, rhythmic coordination, strength (explosive) and flexibility assisted the anthropometric compositions in the review so as to rule out the basic motor abilities considered relevant for success. In the study by miletic [20] and presbyzein, [22] motor ability is defined by the variables containing regulated body weight and basic elements (jumps, balance, rotation and flexibility) irrespective of the apparatus used (rope, ball, hoop, clubs or ribbon). Thus, the basic elements of rthymic gymnasts are characterized by movements with large amplitudes predominated in all routines. The development of strength and flexibility might allow gymnasts to perform more skillfully by increasing the height and length of the jumps in different routines. [18]

CONCLUSIONS

The present systematic review emphasized the role of anthropometric variables in different era's i.e. rhythmic, acrobatic, artistic gymnastics on a single platform. Anthropometric characteristics along with flexibility, explosive strength, aerobic capacity, body dimensions, and metabolism are important factors which contribute to better execution of gymnastic routines. The significant association of these determinants with performance supports the need to include in talent detection and adds another dimension to gymnastics. Nevertheless, coaches should be aware of these specific attributes to improve talent identification and training of gymnasts.

Table1: Details of the studies included in the analysis of the role of anthropometric characteristics in the contribution of performance in gymnastics.

Author (year) Design	**Doudaet al (2008) [18] Observational**	**Mohammad A (2015) [19] Observational**	**Miletic et al (2004) [20] Observational**	**Iglesias TY et al (2017) [21] Observational**	**Przybycień SK et al (2019) [22]**
Subjects (n)	n= 34 Rhythmic gymnasts elite (n=15) non-elite (n=19)	n= 36 female Rhythmic gymnasts	n = 50 female Rhythmic gymnasts	n=150 males and femalesAcrobatic gymnasts	n=53 male Artistic gymnasts seniors (n=19) juniors (n=34)
Mean age	13.41 ± 1.62	9.58± 1.81	7.10± 0.3	13.31 ± 3.1	seniors 21.3 ± 2.62 years juniors 14.3 ± 2.15 years
Anthropometric variables	height,body mass,armspan, sitting height, skinfold thicknesses(triceps and calf)14 circumferences (shoulder, chest, waist, abdominal, buttocks, proximal thigh, midthigh, distal thigh, calf, ankle, arm, forearm, and wrist) and 8 diameters(biacromial, chest, biiliac, bitrochanteric, knee, ankle, elbow, and wrist)	age, height, Weight,biceps skinfold, triceps skinfold,suprailliac skinfold and calf skinfold	weight ,height, biacromial diameter, wrist length, foot diameter, abdomen circumference, forearm circumference, upper leg circumference ,tricepsskinfold, subscapular skinfold and abdomen skinfold	height ,sitting Height,breadth, 8 skinfolds (triceps, biceps, subscapular,supraspinal, suprailiac, abdominal, thigh and medial calf) 5 breaths (biacromial,biliocristal,trochlear condyle of thehumerus, bicondyle of the femur and wrist bistyloid),5 girths(upper arm relaxed, upper arm flexed and tensed,thigh,minimum abdominal and maximum calf)	body length, skeletal system mass, muscle mass, skinfold thickness, and body mass
Other variables	Physical fitness, physiological measurements	Performance scores in the competition was treated as the performance of the subjects (points)	13 motor and 20 specific rhythmic gymnastics tests.	BMI, somatotype, body composition and proportionality	Body composition Somatotypes,handgrip strength, body balance, power of the lowerlimbs (CMJ).
Performance results	Selected anthropometric characteristics are important determinantsof successful performance.	Age, height and triceps skinfold significantly affectthe performance of the gymnasts.	Selected anthropometric traits forms the basis to facilitate the Performance as well as the speed in terms of movement frequency.	Body height, sitting height, minimum abdominal circumference, body fat percentage and low bilocristal diameter were the best predictors of Performance in the base role in female pairs.	A high skill level in a mesomorphy somatotype component, lower limb index, pelvi-acromial index and relative HGSmax accounts for the success of gymnasts.

Author (year) Design	**Vandorpe B (2011) [23] Observational**	**Classens et al (1999) [7] Experimental**	**Rutkauskaitė R et al (2012) [24] Experimental**	**Rutkauskaitė, Ret al (2011) [25] Experimental**	**Di Cagno et al. (2009) [26] Observational**	**Classens et al (1991) [8] Observational**
Subjects (n)	n=168 Artistic female gymnasts elite(n = 103) Sub-elite (n=65)	n=168Artistic female gymnasts	n=10 Rhythmic male and female gymnasts	n=15 Rhythmic male and female gymnasts	n=24 Rhythmic 12 male and 12 female gymnasts	n= 165Artistic male gymnasts
Mean age	6 – 8 years	16.5±1.8 years	14-15 years	13-14year	22±4 years	21.9±2.4 years
Anthropometric variables	Height, sitting leg length. Body weight and body fat percentage	anthropometric variables, skinfolds	height, body mass components (body mass, body mass index BMI, subcutaneous body fat percent)	height, body mass components (body mass, body mass index BMI, subcutaneous body fat percent)	stature, sitting height, body mass, thigh length, triceps, subscapular, suprailiac skinfolds. BMI, sitting-height-to-stature-ratio, fat-free mass and fat mass.	age, weight, height, sitting height, leg length, forearm length, biacromial and biiliac diameter, humerus width, femur width, girths (biceps upper arm , forearm, thigh, calf) skinfolds (biceps, triceps, subscapular, suprailiac, calf)

Table 1: to be continued…						
Other variables	Physical performance, motor coordination	Somatotype, skeletal maturation of hand wrist	Physical fitness, mental fitness, technical fitness, aerobic capacity	Physical fitness, technical fitness	Explosive leg power (squat jump, Countermovement jump, Hopping test) Technical jumps (Split Leap with stretched Legs (SL); Cossack with 180◦ of rotation (CK); Jeté with turn (JWT))	Somatotypes
Performance results	Anthropometric characteristicsare valuable determinants of successful performance.	Anthropometric characteristicssignificantly affect the success of gymnasts.	Anthropometric characteristics are valuable determinant of successful performance	Anthropometric characteristics are significant indicators that determines the efficacy of gymnasts performance.	Anthropometric characteristics have to be attained to reach high results for both genders. Low fat mass and sitting-height-to-stature-rationalues and high Fat free values, stature and lower limb length, could be considered as important variables in rhythmic gymnast performance	Significant differentiations in anthropometric traits are observed indicating that physical characteristics are selective parameters for top level artistic gymnasts.

Author (year) Design	**Hume (1993) [27] Cross sectional study**	**Rutkauskaite& Skarbalius (2009) [28] Observational**	**Pool J et al (1969) [29] Observational**	**Faria IE and Faria EW (1989) [30] Observational**	**Iglesias T et al (2016) [31] Observational**
Subjects (n)	n =106female Rhythmic gymnasts	n=25 Rhythmic gymnasts male and female	38 artistic female competitors of the European championship.	n= 65 artistic male Class I and II all-around gymnasts were compared with 11th to 34th in the all-around scoring at the 1987 U.S. Gymnastics Federation Junior Olympic National Championships.	n= 150 acrobatic gymnasts n=129 women n= 21 men They were divided into top and bases depending on their role.
Mean age	7-27 years	11-12 year	--	--	--
Anthropometric variables	age, lean body mass, flexibility, leg power, maximum oxygen uptake and visuo-motor proficiency.	height in the standing position and body mass components (body mass, body mass index, subcutaneous bodyfat).	Height, weight, leg length, thorax width, bicondylarfemur diameter, arm and calf circumference, triceps and subscapular skinfold	anthropometric measurements, body composition	anthropometric measurements, morphological measurements
Other variables	Training and psychological measures	Physical fitness, mental fitness, technical fitness	Handgrip strength, jumping height, running time, running distance.	power, strength, and flexibility	proportionality and somatotype
Performance results	Age, lean body mass and composite measures of flexibility, leg power and visuo-motor proficiency showed significant correlates of attainment (r = 0.69-0.29), as were coach democratic and coach social behaviors	The impact of body compositions indices, was greatly affected by all indices of technical fitness (integral index of athletic fitness, explosive strength and endurance	Anthropometric characteristics specifically height, weight, thorax width are significant for the efficacy of gymnasts jumping performance.	To Class I and Top Class II when compared to other classes were characterized as shorter in stature, stronger in both relative and absolute strength, possessed greater flexibility through the hip region, shoulder girdle, back, were leaner, and possessed more muscle mass.	Trochlear condyle of the humerus, the bicondyle of the femur and the wrist bistyloid breadth in tops and the wrist bistyloid breadth, the upper arm relaxed girths and maximum calf in bases showed positive results. The best prediction model included thigh girth as the best explanatory covariate of role performance.

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