MOTOR PERFORMANCE OF BRAZILIAN FEMALE ARTISTIC GYMNASTS: INSIGHTS VIA MULTILEVEL ANALYSIS

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Original article

Abstract

The aim of this research was to investigate individual and club-level variables that explain individual differences in gymnasts´ motor performance (MP). The sample was comprised of 249 female gymnasts (68 elite; 181 non-elite), aged between 9 and 20 years, split into four age categories: 9-10 years (n=98); 11-12 years (n=72); 13-15 years (n=64), and 16 and above (n=15). Gymnasts were from 26 Brazilian clubs, from six different states. The Talent Opportunity Program physical ability total test score was used to assess gymnasts' MP, based on a battery of seven tests: handstand hold, cast, rope climb, press handstand, leg flexibility, leg lift, and 20 meter sprint. Anthropometric, body composition, biological maturation, and training history data were also collected, as were club dimensions, infrastructures, competitions, manpower, and availability of selection/talent programs. Data were analyzed using a multilevel modelling approach. Individual gymnast' characteristics explained 39% of physical ability score variance from which 32% was related to the independent effects of age, competitive level, fat free mass, occurrence of menarche, and trainings hours per week (p<0.05). Club characteristics explained 61% of gymnasts' total variance in physical ability score; 96% of this amount was related to club dimension, manpower, and talent program. These results reinforce the relevant role of the contextual effects and highlight the need to invest in club infrastructures: ideally in coaches' expertise and effective selection programs. Such investments should enable the enhancement and development of a gymnast's careers during their lifetime involvement in training and competition.

Keywords: *physical fitness, performance, gym club.*

INTRODUCTION

Elite women artistic gymnasts (WAG) differ from their peers in their: physique aesthetics, explosive power and specialized skills, and their technical perfection in each of the elements (Bradshaw, Hume, & Aisbett, 2011). Although gymnast's high performance levels may express different genetic endowments (Morucci, Punzi, Innocenti, Gulisano, Ceroti, & Pacini, 2014), it is also acknowledged that performance is related to training conditions, continuous competition engagement, and coaching excellence (Côté, 1999).

It has always been challenging to assess gymnasts' motor performance (MP), apart from specialized skill-oriented tasks (Marina, Jemni, & Rodriguèz, 2013). A gymnast's physical attributes (Bajin, 1987; Vandorpe, Vandendriessche, Vaeyens, Pion, Lefevre, Philippaerts et al., 2011) interact with, and reflect, motor components (Sands, 2011), with the greatest emphasis's placed on strength and explosive power, flexibility and artistry (Bale & Goodway, 1990). The putative MP measurements are made difficult by having a complex set of parameters such as technical skills, muscular contractions and speed of stretch (Monèm, 2011). However, test batteries to assess MP have been developed to identify specific gymnastics motor profiles (Albuquerque & Farinatti, 2007), and to identify giftedness amongst gymnasts (Bajin, 1987; USA-Gymnastics, 2014). The new 2014 Talent Opportunity Program (TOP) offers a comprehensive test battery for gymnastics and it has been suggested that the resulting scores (TOPS total score - TTS) could be used in talent identification programs (USA-Gymnastics, 2014).

Since gymnasts spend considerable amounts of their sport life time training in their clubs, it is likely club infrastructures, competition schedules, number and quality of coaches, as well as selection programs may affect their MP. For example, manager/coach, pay/salary and training conditions ((Kayani, Zia, & Abbas, 2012), human resources in achieving organizational objectives, the relationship between human resources and sports performance ((Mihaela, Veronica, & Dana, 2014), and the joint effects of individual and group level covariates (Hill, Stoeber, Brown, & Appleton, 2014; (Petitta, Jiang, & Palange, 2015) have all been shown to be related to a gymnasts performance.

The aim of this research was to investigate individual and club-level variables that explain individual differences in gymnasts′ motor performance (MP).

METHODS

The sample comprises 249 female gymnasts [68 elite (EG); 181 non-elite (NEG)] aged 9-20 years. They were separated into four age categories according to the Brazilian Gymnastics Federation competition rules (CBG, 2015): 9-10 years (n=98); 11-12 years (n=72); 13-15 years (n=64), and ≥16 yeas (n=15). Gymnast were classified as EG or NEG using the following criteria: NEG are those who participated in regional or state championships, or competed at the national championship but were classified below the 10th position (all-around classification); EG are those who either participated in national championship and had been classified between the 1st and the 10th position in the final ranking (all-around classification), or who had participated in international championships. Gymnasts were selected from 26 Brazilian gymnastics clubs, representing ~60% of all clubs in a state. Clubs were selected based on their participation and classification in the 2014 Official Brazilian Championships. All gymnasts included in the study (Table 1) were identified by their coaches and were part of the main team in each club. The study protocol was approved by the ethics committee of Dom Bosco Catholic University (CAAE 42967215.9.0000.5162), as well as by the technical director of all the Gymnastics Clubs. Written consent forms were obtained from parents or legal guardians of gymnasts, as well as assent from all gymnasts.

The Talent Opportunity Program physical ability testing score (TTS), (USA-Gymnastics, 2014) was calculated from a battery of seven MP test: handstand hold; cast; rope climb; press handstand; leg flexibility; leg lift; and 20 meter sprint. Each of the 7 test scores was scored between 0-10 points, except leg flexibility which was scored between 0-12 points. The upper limit of the TTS is 72 points, and a higher score indicates better MP.

All anthropometric measurements were made according to standardized protocols (Ross, & Marfell-Jones, 1991). Height and sitting height were measured to the nearest 0.1cm using a portable stadiometer (Sanny Stadiometer, SP, BR) with the head positioned in the Frankfurt plane. Body mass (Kg) was measured with a portable bio-impedance scale (Tanita SC 240 Body Composition Analyser scale, IL, USA) with a 0.1kg precision. Leg length was calculated as the difference between standing height and sitting height. All measurements were performed at the beginning of each training session.

Body composition was estimated from regression equations provided by the manufacturer of the bio-impedance Tanita SC 240 scale (Tanita SC 240 Body Composition Analyser scale, IL, USA) which were unavailable to researchers. In the present study, fat mass (Kg), free fat mass (Kg), and percent fat (%Fat) were considered.

Biological maturity was obtained using data from menarche occurrence (yes or no) as well as from predicting age from (maturity offset) the attainment of peak height velocity (PHV) using a anthropometric variables (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). In girls, the predictive equation is: Maturity Offset=-9.376 + 0.0001882 * leg length and sitting height interaction + 0.0022 * age and leg length interaction + 0.005841 * age and sitting height interaction - 0.002658 * age and weight interaction + 0.07693 * weight by height ratio. A positive (+) maturity offset indicates the number of years the participant is beyond PHV, whereas a negative (-) maturity offset represents the number of years the participant is prior to the attainment of PHV.

Athletes answered questions regarding their onset of training, training years, onset of competition, as well as the number of training hours per week. These answers were cross-checked with their parental as well as coaches' reports. When inaccuracies were found, we relied on the information provided by the coach.

Information about all gymnastic clubs was obtained via questionnaire which was developed in accordance with an expert panel of gymnastics coaches and researchers from Brazilian and Portuguese clubs and Sport Sciences colleges. It was centered on 5 domains: (1) club dimensions; (2) infrastructures; (3) competition; (4) manpower; (5) selection/talent programs. Club managers or persons with similar functions answered all questions.

Club dimensions (CD) recorded information about the total number of women artistic gymnasts (WAG) practicing at the club. A dummy coding schema was used to categorize the responses: CD=0 if up to 50 gymnasts (reference category); CD=1 if between 51 to 150 athletes; CD=2, if 150+ gymnasts. Further, the number of gymnasts per team was assessed (GPT). GPT=0 if gymnasts ≤6 (reference category); GPT=1 if 7 to 10 gymnasts; and GPT=2, if >10 gymnasts.

Infrastructures included questions about the exclusive use of the club for gymnastics, availability of complete sets of WAG apparatuses and Pit (foams' pool for security used in the end of or under gym apparatuses) in the gym. These variables were binary coded 1=yes or 0= no.

In this domain questions were related to WAG lifetime (LT) in the club. This was coded in the following way: LT=0 if up to 4 years (reference category), LT=1 if 5 to 10 years, and LT=2 if ≥11 years. Participation in international competitions was also recorded, binary coded as 1=yes or 0=no.

Manpower included questions about the amount of WAG coaches (C): C=0 if <=to 4 coaches, and C=1 if >4 coaches. Further, coaches experience (CE) was also recorded in years, in competitive WAG:

CE= 0 if <=4 years, CE=1 if >4 but <10 years, CE=2 if ≥10 years but < 20 and CE = 3 if ≥20 years.

In this domain questions were asked about the way the gymnasts' search/selection was made, because most selections are made external or internal to the club. As such our reference variable (0) was if selection (S) made externally in groups of children interested to participate in gymnastics: S=1 if external from club but from children already participating in gymnastics; S=2 if internal to the club, and S=3 if different from the previous. A second question was about the systematic use of tests in selection, coded as 0 (reference category, meaning "no") and 1 (yes, they use).

Exploratory and descriptive statistics were performed in SPSS 20.0. Mean differences between EG versus NEG, in each age group, were calculated in STATA 14, using a t-test with a Satterthwaite's approximation for degrees of freedom, since in most cases the variances were not equal between the groups. Alpha was set at p=0.01. Mean differences for relative (%) data were performed in WinPep software (Abramson, 2004).

Since our data was clustered, i.e., gymnasts (level-1) nested within clubs (level-2), we used a hierarchical multilevel model and data were analyzed using Supermix v.1 software (Hedeker, D, Gibbons, R, du Toit, M, & Cheng, Y, 2008). A sequence of nested models was developed and tested as is common in multilevel modelling (Hox, 2010). We started with a simple model and then added predictors, i.e., we increased the model complexity. Simpler models are contained in more complex models, i.e., they are nested within. Deviance is the usual statistic that describes the goodness of fit of a model. More complex models in terms of explanatory power as well as in number of parameters, i.e., with more predictors, are expected to have lower values of Deviance. Differences in Deviances follow a Chi-Square distribution with degrees of freedom equal to the difference in the number of parameters of both models (Hox, 2010). Further, the relevancy of individual and club-level predictors to explain TTS variance was assessed with a pseudo-R^2 (which is similar, in a way, to the R^2 of multiple linear regression), and is defined as the proportional reduction in variance resulting from a comparison of a new model with a previous one (Hedeker et al., 2008). Modeling was performed in a sequential fashion as is usual when using any statistical model to explain any outcome variable – in our case TTS. First a Null model (M0) was estimated to compute the intraclass correlation, i.e., the variance accounted for by clubs' effects on gymnasts' TTS – the main issue here is to answer the fundamental question: are clubs important in explaining gymnasts´ TTS scores? Then, in Model 1 (M1) we only included gymnasts' TTS predictors. Finally, in Model 2 (M2), we added club predictors. This is, in fact, our most complex model in terms of explanatory power and also in the number of parameters to be estimated.

RESULTS

Gymnasts' descriptive statistics (means ± standard deviations and percentages) are shown in Table 1. As expected, the EG had significantly higher TTS's (p<0.01). However, there were no differences in size, maturation or body composition between gymnasts at any age group (p>0.01) apart from significantly more NEG 13-15 year old's attaining menarche (p<0.01). There were also no differences in the age of training onset or training years between the groups (p>0.01), however the GE, 11-12 and 13-15 year old's performed significantly more training hours per week (p<0.01).

Table 1
*Descriptive statistics by level of gymnastics (*non-elite *-NEG and elite-EG) and age group.*

	9-10 yrs n=98		11-12 yrs n=72		13-15yrs n=64		> 15 yrs n=15	
Competitive Level	NEG n=84	EG n=14	NEG n=45	EG n=27	NEG n=41	EG n=23	NEG n=11	GE n=4
Age (yrs)	9.49±0.50	9.86±0.36	11.51±0.51	11.52±0.51	13.76±0.73	13.57±0.66	17.00±0.78	17.50±1.92
TTS	26.68±13.11*	45.07±13.60	25.47 ±13.90*	48.11±13.99	34.96±15.54*	53.52±10.10	30,63±13,44	52,66±7,68
Weight (kg)	29.03±3.88	30.84±4.19	37.59±7.37	35.20±6.97	47.37±7.65	43.54±4.95	53.78±5.11	52.40±4.06
Height (cm)	134.69±6.22	135.76±5.91	146.12±7.16	142.64±6.60	154.23±6.98	150.84±4.76	159.33±4.28	159.18±4.97
Free Ft Mass (kg)	24.17±2.92	25.30±3.03	30.37±4.34	28.66±3.98	36.53±4.60	34.37±2.99	42.72±2.54	40.96±1.75
Maturity Offset	-2.71±0.49	-2.37±0.47	-1.07±0.60	-1.28±0.60	0.61±0.79	0.29±0.57	2.76±0.50	3.00±1.27
Menarche occurrence	3 (3.60%)	-	5 (11.10%)	3 (11.10%)	30 (73.20%)*	7 (30.40%)	11(100%)	4(100%)
Training onset (yrs)	5.84±1.53	5.07±1.33	6.55±2.05	5.82±1.27	6.40±2.01	6.00±1.41	8.09±2.38	5.50±1.91
Training years (yrs)	3.89±1.91	5.11±1.60	5.13±2.19	5.92±1.75	7.43±2.32	7.91±1.56	9.27±2.80	11.75±4.71
Training hours ($h \cdot w^{-1}$)	20.66±7.03	24.39±4.35	19.40±8.88*	28.20±3.09	21.7±8.8*	30.13±4.21	24.00±8.31	27.75±3.50
Competition onset (yrs)	7.52±1.51	6.85±1.19	8.05±1.69	7.59±1.21	8.24±1.54	7.61±1.23	9.27±1.90	8.25±0.50

*p<0.01

Table 2
Variable domains and their results at the club level.

Club dimension	
Total Number of Gymnasts - WAG$^{(1)}$	
Up to 50 gymnasts	23.00%
51 - 150 gymnasts	38.50%
Over 150 gymnasts	38.50%
Number of Gymnasts per team	
Less than 6 gymnasts	34.60%
7 - 10 gymnasts	42.30%
More than 11 gymnasts	23.10%
I*nfrastructures*	
Exclusive place for gymnastics	
No	7.70%
Yes	92.30%
Complete Apparatuses of WAG and Pit$^{(2)}$ in the gym	
No	30.80%
Yes	69.20%
Competition	
Lifetime of WAG in the club	
Up to 4 years	11.50%
5 to 10 years	15.40%
Over 11 years	73.10%
Gymnasts with participation in International Competitions	
No	50.00%
Yes	50.00%
Manpower	
Amount of WAG coaches in teams	
Up to 4 coaches	92.30%
5 to 10 coaches	7.70%
Coach time experience in competitive WAG	
Up to 4 years	15.40%
5 to 10 years	34.60%
11 to 20 years	26.90%
More than 20 years	23.10%
Talent programs	
The way in which the selection of gymnasts is performed.	
Externally (evaluating girls still no exercise practitioners)	7.70%
Externally (evaluating girls who already practice or practiced gymnastics)	15.40%
Internal form (evaluating girls already practicing gymnastics at the club)	53.80%
Another (not identified way).	23.10%
Use of tests in gymnasts selection	
No	15.40%
Yes	84.60%

WAG$^{(1)}$ = Women's Artistic Gymnastics, Pit$^{(2)}$=security place for training

Table 3
Results summary of hierarchical linear modeling.

Parameters	Null Model			Model 1			Model 2		
	Estimates	SE	p	Estimates	SE[1]	p	Estimates	SE	p
Fixed Effects									
Gymnasts Level									
Intercept	34.80	2.72	<0.01	27.70	1.85	<0.01	42.02	6.77	<0.01
Age Categories				4.17	1.31	<0.01	4.07	1.33	<0.01
Competitive Level				11.16	2.28	<0.01	11.98	2.25	<0.01
Free Fat Mass (kg)				-0.34	0.13	<0.01	-0.36	0.13	<0.01
Menarche occurrence				11.57	4.43	<0.01	11.54	4.38	<0.01
Training hours/per week ($h \cdot w^{-1}$)				1.12	0.13	<0.01	1.22	0.13	<0.01
Age Cat[2]-by-Comp Level[3] Interaction				-2.21	1.59	>0.01	-3.01	1.58	>0.01
Menarche occurrence-by-Age Cat Interaction				-4.46	2.13	>0.01	-4.47	2.12	>0.01
Club Level									
Club dimension									
Total WAG: 51 -150							-7.15	3.31	>0.01
Total WAG: over 150							3.94	2.75	>0.01
Gymnasts per team: 7 - 10 gymnasts							-4.16	2.21	>0.01
Gymnasts per team: More than 11 gymnasts							-9.32	2.60	<0.01
Manpower									
Number of WAG coaches in teams							-7.99	4.06	>0.01
Coach time experience									
5 to 10 yrs							0.31	3.38	>0.01
11 to 20 yrs3							7.40	3.61	>0.01
More than 20 yrs							4.25	3.11	>0.01
Talent/Selection programs									
Selection externally (already practitioners)							-21.55	6.22	<0.01
Selection internally at the club							-12.11	4.73	<0.01
Another selection process (not identified)							-12.12	4.83	<0.01
Use of tests in gymnasts selection							7.41	2.84	<0.01
Random effects									
Intercept	177.32			39.43			7.20		
Residual	115.95			79.19			79.38		
Deviance (number of parameters)	1951.44 (3)			1802.53 (10)			1775.28 (22)		

SE[1]= Standard Error, Age Cat[2]= Age Categories, Comp Level[3]= Competitive Level, WAG[4]=Women´s Artistic Gymnastics.

Clubs' descriptive statistics are shown in Table 2. Nearly 80% of clubs had more than 50 gymnasts and at least 4 coaches with between 5 and 20 years of experience. A third of the clubs had 6 gymnasts in a team and over a half had athletes participating in international competitions, with the majority having competed for over 11 years. Most clubs were exclusively for gymnastics and over two thirds had a pit and complete sets of apparatuses. The most frequent mode of selection into the sport was internal to the club (54%), and most clubs (85%) used tests to identify talent.

The results of the multilevel models are shown in Table 3. In the Null Model (M0), the intercept (fixed effects) represents the average TTS points (β=34.8±2.7) for all gymnasts. Variance between gymnasts and between clubs is shown in the random effects; the intraclass correlation coefficient (ICC)=0.61, implies that 61% of the total variance in gymnasts' TTS is explained by club level covariates; further, the remaining variance, 39%, is explained by differences in individual gymnasts' characteristics.

M1 fitted the data better than M0 indicated by a reduction in goodness of fit from 1951.4 to 1802.5 ($p<0.01$). The intercept of M1 (β=27.7±1.9, $p<0.01$) represents the TTS for a gymnast from the reference group (9-10 yrs old). TTS increased with increasing age category (β=4.2±1.3, $p<0.01$); further, EG gymnasts scored higher on TTS (β=11.2±2.8, $p<0.01$) when all other confounders were controlled. Gymnasts with higher free fat mass performed worst in TTS (β=-0.3±0.1, $p<0.01$). The higher the number of training hours per week the better the performance (β=1.1±0.1, $p<0.01$). Experiencing menarche was positively associated with TTS scores (β=11.6±4.4, $p<0.01$). Taken together, these gymnasts' covariates explained 32% of the 40% inter-individual TTS scores variance.

Since most clubs have similar infrastructures, as well as competition no association was found with TTS ($p>0.01$). M2, with club-level covariates added fitted the data better than M1. In M2, the intercept (β=41.6±6.85, $p<0.01$) is the TTS of a gymnast when all predictors are at zero. Gymnast level covariates remained similar to those in M1. Results from M2 showed that gymnasts from small clubs (less than 50 gymnasts) and small number of gymnasts in team classes, as well as from clubs with less than 4 coaches but with more experience time in training tend to perform better in TTS ($p<0.01$). Further, gymnasts from clubs that had selection tests and who selected gymnasts externally (no practitioners) tend to perform better in TTS ($p<0.01$). Taken together, club-level covariates explained 96% of the ~61% of the between-clubs variance.

DISCUSSION

This paper aimed to identify gymnast and club level characteristics that explained inter-individual differences in motor performance (MP) tests. The main findings indicated that a substantial amount of TTS variance (61%) was attributable to club environment and to a smaller extent (39%) the individual gymnast's characteristics.

Total TTSs score increases of ~4.2 points were observed across age categories, this is similar to a mean increase of ~3 points across 9 to 11 years old previously reported in USA gymnasts (USA-Gymnastics, 2010). Further, a previous study of Brazilian gymnasts, albeit using a different test battery (Albuquerque, & Farinatti, 2007), showed mean increments of 2.5 points among beginners and 3.7 points among elite gymnasts aged 9 to 15 years old. These results confirm the roles of both neuromuscular maturation and experience in performing strength tasks (Malina, Bar-Or, & Bouchard, 2004). In 2010, the American Gymnastics Federation reported TTS averages of 53.47, 56.43 and 59.57 points in 9, 10 and 11 yrs old gymnasts respectively, which are greater than those reported in present sample of Brazilian gymnasts. This may explain in part their higher performances. In our models a constant difference in EG and NEG TTS of ~11.2 points was evident across all age categories, favoring the EG. A similar trend was previously reported between beginners and elite Brazilian gymnasts, but again using a different test battery (Albuquerque, & Farinatti, 2007). (Vandorpe et al., 2011) also found significant differences in physical performance characteristics between non-elite and elite levels, favoring the elite group, even after controlling for age and maturation (age at peak height velocity). These consistent differences could be explained in part by the greater amount of weekly training hours performed by EG.

There was a positive effect of biological maturation on TTS of ~11.6 points, i.e., a superior MP of those who already passed through menarche. However, a statistically significant interaction between menarcheal status and age categories revealed a decrease of ~4.5 TTS points. It has consistently been shown that EG are late maturers (Baxter-Jones, Thompson, & Malina, 2002; Malina, Baxter-Jones, Armstrong, Beunen, Caine, Daly et al., 2013), and since a high frequency of NEG reached menarche prior to EG in each age category this may help explain this interaction.

As expected, the number of training hours per week was positively associated with TTS performance, on average, ~1.2 points. This is in agreement with available data (Vandorpe et al., 2011), given that weekly time in training increases with age and competition level (Malina et al., 2013). As per (Ericsson, Krampe, & Tesch-Römer, 1993) suggestion, more training hours per week provide more deliberate practice which then translates to higher levels of expertise, which is consistent with (Lidor, Tenenbaum, Ziv, & Issurin, 2016) findings.

Results from club-level covariates showed significant associations of club dimensions, manpower and talent programs with gymnasts' TTS development. Gymnasts from larger clubs (over 150 gymnasts) had better performance while those from medium clubs (51 - 150 gymnasts) had worse performance (-7.0) in the TTS. It is possible that these results may be due to the fact that larger clubs have a larger pool to select from and have better opportunities to train them. In contrast, smaller clubs work with those available, who may be less gifted. Team size was negatively associated with performance suggesting smaller teams are prone to more individualized planning, coaches' attention and training together with more systematical assessments and skills enhancement (Asqalan, 2016). In educational settings classes with more students are thought to have a negative influence in educational attainment (Case, & Deaton, 1999), whist small classes, especially in the early grades, lead to higher academic achievement (Nye, Hedges, & Konstantopoulos, 2000). Translating this to gymnastics training, where quality and repetition are very important, more individual attention allows the gymnast to develop a high degree of perfection (Asqalan, 2016).

Gymnasts belonging to clubs with more coaches had worse TTS performance (-8.4 points), at the same time more coaching experience was positively associated with TTS. (Baker, Horton, Robertson-Wilson, & Wall, 2003) highlighted that the coach is most probably one of the utmost significant keys to athlete development and performance. Additionally, more years of experience allow coaches to draw upon their vast and diverse amounts of information about their sport as well as their athletes, since more experience allows better planning, diagnose, and strategize more effectively (De Marco, & Mccullick, 1997). Since the development of expertise is a long-term process, coaches who achieved it are more efficient in detecting what athletes need to know and then find the best strategies to supply that information to them (De Marco, & Mccullick, 1997). As is to be expected, clubs with selection processes had higher TTS scores (Albuquerque, & Farinatti, 2007; Bajin, 1987; Pion, Lenoir, Vandorpe, & Segers, 2015) as did those who teams were selected externally. This is likely associated with a broader recruitment basis together with the fact that decisions are mostly based on innate characteristics that are believed to be mandatory to excel, and not so much on specific technical skills (Meyers, Van Woerkom, & Dries, 2013).

This study has limitations, specifically the sample does not represent all Brazilian gymnasts and care needs to be taken about the generalizability of the findings. However, the sample includes gymnasts from states with higher competitive levels across Brazil. Secondly, the TOPS battery is not widely implemented in Brazil and its importance and applicability in gymnasts' training control is unknown.

CONCLUSIONS

The present study showed that individual gymnast' traits explained 40% of TTS variance, from which 32% was related to the independent effects of age, competitive level, fat free mass, menarche occurrence, and trainings hours per week, i.e., older, lighter and mature gymnasts, as well as those belong to the elite group that train more hours per week perform better. Moreover, club characteristics explained 61% of gymnasts' total variance in TTS performance, and 96% of this amount is related club dimension, manpower, and talent program, reinforcing the relevant roles of contextual effects, which highlights the need to also invest in club structures, mainly in coaches' expertise as well as in effective selection programs to develop and enhance gymnasts' carriers during their lifetime involvement in serious training and competition.

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