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Assessing Young Gymnasts' Dynamic Posture: A Comparison of Methods

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Abstract

Functional Movement Screen is an established method of assessing dynamic posture of athletes. Validity and reliability of FMS as a screening tool is debated and one of the foremost criticism is directed at its subjectivity. To the authors' knowledge, there is no previous research using Kinovea to precisely assess FMS scores.

10 young competitive gymnasts (4 female and 6 male) were included in this study. The participants were scored by an experienced FMS assessor on site as per standard FMS protocol. Afterwards, the same participants were scored again using Kinovea to achieve more objective measurements.

Wilcoxon Signed Rank Test for FMS scores versus FMS-Kinovea scores identified FMS test no. 1 (Deep Squat) as significantly different. The median score of Deep Squat assessed on site was 2 (mean value: 2.1), while that same test, scored with Kinovea, had the median score of 1 (mean value: 1.2). Paired Pitman-Morgan test for equality of variances was used to test the dispersion of scores. None were shown to be statistically significant, however, overall FMS score was near significance threshold implying that there is a difference although our power of study was too low probably due to low sample size.

We detected significant difference in the scores of Deep Squat test, which is not surprising since it is the most complicated test to asses due to a large number of variables the assessor must evaluate.

Keywords: Dynamic posture, FMS, Kinovea, artistic gymnastics

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Introduction

Artistic Gymnastics, as one of the oldest sports of the modern Olympics, developed into a specific branch of sports from general gymnastics, which historically represent the system of physical training in its whole. From the 19th century onwards, owing greatly to its appearance at the modern Olympics in 1896, we classify Artistic Gymnastics as an independent, competitive branch of sports. Accordingly, it has since been classified as having a large amount of exercises, methodical procedures of learning specific movements as well as a complex competitive curriculum. All of this resulted in Artistic Gymnastics becoming one of the fundamental branches of sports. We may define Artistic Gymnastics as a branch of sports in which gymnasts use various types of apparatus to perform exercises which consist of a series of diverse gymnastic elements and their combinations. The International Gymnastics Federation (*Fédération Internationale de Gymnastique-FIG*) defines Artistic Gymnastics as an Olympic sport divided into Men's and Women's Artistic Gymnastics, which differ in the number and type of gymnastic events. Male gymnasts present their gymnastics skills in six gymnastic events: Floor Exercise, Pommel Horse, Still Rings, Vault, Parallel Bars, and Horizontal Bar; female gymnasts compete in four events: Vault, Uneven Bars, Balance Beam, and Floor Exercise. Each event requires them to perform a series of complex gymnastics elements interconnected to form a whole, which is called gymnastic exercise. Women's and Male's Gymnastics have two matching events: Floor Exercise and Vault. It is a widespread opinion amongst gymnastics experts that the Pommel Horse is a typically "male" apparatus, with the Beam being typically "female".

Artistic Gymnastics, as one of the basic motor activities, is listed into the group of conventionally aesthetic sports according to the criterion of structural complexity of movement[1] and into aerobic sports according to the criterion of dominant energy processes. The most important motor skills are coordination, explosive strength, flexibility, balance and speed.

As many as 1327 technical elements appear in the manuals, including Manuals of both Women's and Men's Artistic Gymnastics. The prescribed techniques of 527 elements can be found in the Manual of Women's Artistic Gymnastics (Vault 80; Uneven Bars 155; Beam 189, Floor 103), and we can find as many as 800 prescribed techniques of gymnastic elements in the Manual of Men's Artistic Gymnastics (Floor 137; Pommel Horse 118; Rings 144; Vault 104; Parallel Bars 155; Horizontal Bar 142). Each technique has its specific application in various performance of exercises, and all of them have roots in the basic structures of gymnastic movements: forward and backward roll, dive cartwheel, front and back walkover, elementary forms of the salto and elements on apparatus which are executed through static holds and static hangs[2].

The volume of prescribed techniques highlights the importance of choosing the best way of teaching basic and advanced elements, didactically and methodically, as well as using the best exercises to form the movement structure of each element. There are many examples from practice, from classifications of technical elements performed on certain Women's Artistic Gymnastics' apparatus to performing basic elements on Women's Artistic Gymnastics' apparatus using biomechanical analysis to help trainers, as well as specific tests designed to assess those motor capabilities important for Artistic Gymnastics. One of the latest examples of using tests to assess motor skills in Artistic Gymnastics is the application of the Functional Movement Screen Test (FMS). Dave Tilley conducted such a test in 2016 on the members of the Olympic gymnastics team, among which was Simone Biles, the winner of five gold medals at the Rio 2016 Summer Olympics.

The Functional Movement Screening (FMS) is a screening tool that consists of seven tests, each graded 0 to 3 with a maximal composite score of 21. In each test, assessor observes athletes' movement and scores accordingly. In order to receive a grade of 3, the athlete must perform the movement with minimal deviations and compensations[3]. FMS can be performed live, with the assessor grading on-site or via video analysis in which assessor grades the test off site using movement analysis software[4].

Main purpose of our study was to compare the results of on site and off site FMS. Specifically, we wanted to analyse if there are any differences between on site and off site FMS results, as well as test equality of variance between them. Our working hypothesis is that there are differences in central tendencies of FMS test results as well as inequality of variance. We hypothesise that FMS evaluated by motion analysis software will produce more stringent results using the same criteria as on-site assessment. Likewise, we believe that off-site assessment will produce less variance in test scores. To the best of our knowledge there are no similar, previously published studies.

Methods

The sample comprised 10 competitive young gymnasts (6 males and 4 females). On-site assessment was performed using standard FMS scoring [5]. The FMS consists of seven subtests: the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability tests [6]. All subtests except the shoulder mobility subtest were recorded using two digital video cameras Canon EOS 550D. Digital cameras were positioned on the antero-posterior and latero-lateral axis in relation to the athlete being assessed. Off-site assessment was performed using Kinovea motion analysis software. According to the FMS protocol, each subtest is performed 3 times and the best repetition is scored. It is important to note that the same repetition of the FMS subtest was scored both on site and off site. On-site and off-site scoring was performed by the same assessor with a 6 months gap between assessments.

On-site FMS scoring was graded by original criteria proposed by Cook[6]. Off-site scoring was graded according to quantified criteria by Whiteside et al.[7] and modified by Kiseljak et al.[8]

It is important to note that criteria for Kinovea enhanced FMS grading are the same as the original FMS criteria. The main difference between them is the quantification of criteria. In the original FMS, the criteria is based on quick and subjective observation. In Kinovea enhanced FMS, cut-off values for the criteria are well-defined and easily reproduced in other assessments. Comparable criteria are presented in Table 1.

Basic sample parameters, subtest scores and the composite FMS score are summarized by descriptive statistics. Differences in FMS and FMS–Kinovea are tested via Wilcoxon Signed Rank test due to low sample size. Paired Pitman-Morgan test was used to compare the variances of the two groups. The variances were tested in order to compare precision and reproducibility[9]. Increased probability of Type I error, due to multiple comparison problem, is adjusted by controlling for false positive results using Benjamini & Hochberg method[10]. Statistical analysis was performed using R, version 3.4.3. Packages used were: *"readxl", "data.table", "broom", "psych" and "PairedData"*. All measurements, data analysis and confidentiality of participants data was done in accordance with Ethical Research Involving Children (ERIC).

Results

10 young gymnasts were measured, six males and four females. Basic anthropometric characteristics, such as age, height, weight and BMI of the participants are presented in Table 2. Although differences in groups were tested by Wilcoxon Signed Rank Test, the mean and standard deviation of all subtests, as well as the summed score, are shown in Table 3 for reader convenience.

The results of Wilcoxon Signed Rank Test for FMS scores versus FMS-K scores are summarized in Table 4. Only FMS subtest 1 (Deep Squat) has shown significant difference ($p=0.04$). FMS subtest 1 median scores for Kinovea enhanced FMS and standard FMS are 1 and 2, respectively.

All subtests, as well as the composite FMS score have equal variances between standard FMS and Kinovea enhanced FMS (Table 5). However, summed composite score has the largest difference in variance, 0.84 for standard FMS and 0.39 for Kinovea enhanced and lowest p value (0.07 unadjusted, 0.39 adjusted for multiple comparisons).

Discussion

Our working hypothesis is that Kinovea based FMS will produce lower grades since it is easier to observe any errors in the tests performed by athletes. No significant differences were detected in the composite score as well as in most of the subtest scores. Only FMS 1, Deep Squat, has shown difference between standard FMS and Kinovea enhanced FMS. The median score for standard FMS was 2, ($\bar{x}=2.2$), and for Kinovea enhanced FMS the median was 1 ($\bar{x}=1.2$). Such results are not very surprising, because deep squat is biomechanically very complex[11] and as a result, FMS 1 has the largest number of criteria that must be observed by the assessor. It is logical that errors in execution of deep squat will be much more visible using video based kinematic analysis, which contributes to low overall score for FMS 1. Median composite FMS score was lower in Kinovea enhanced group (14 versus 15.5). Even though that dif-

Table 1. **FMS scoring criteria**[a]

Standard FMS scoring criteria	Kinovea based analysis scoring criteria [a]
FMS 1: Deep Squat	
Upper torso is parallel toward vertical	Trunk lateral shift < 10°
Upper torso is parallel with tibia	Trunk sagittal shift < 20°
Knees are aligned over feet	Calf lateral shift < 15°
Dowel aligned over feet	AP shift from line passing through ankle joint < 15 cm
FMS 2: Hurdle Step	
Hips, knees, and ankles remain aligned in the sagittal plane	LL shift of calf < 15°
Dowel and hurdle remain parallel	Shift from hurdle parallel < 7,5°
FMS 3: In-line lunge	
Dowel remains vertical + No torso movement	AP or LL shift < 7,5°
Knee touches board behind heel of front foot	Vertical or AP knee displacement < 5 cm
FMS 5: Active Straight Leg Raise	
Beyond the middle of the thigh (score 3)	Distance from line through lat. malleol is > half of thigh length
Between the middle of the thigh and the knee (score 2)	Distance from line through lat. malleol is < half of thigh length
Not beyond the knee (score 1)	Distance from line through lat. malleol is < thigh length
FMS 6: Trunk Stability Push-up	
Body lifts as a unit with no lag in the spine	No deviations from line connecting sacrum, thoracic kyphosis and occipitum
FMS 7: Rotary Stability	
Performs a correct unilateral repetition	Hyperextension in hip joint
	Distance from elbow to knee joint < 10 cm

[a]Based on[7], modified by[8]

Table 2. **Basic parameters**

	$\bar{x}$	*SD*	Median	Min	Max
Age (years)	11.52	0.55	11.41	10.59	12.68
Height (cm)	138.3	4.6	136.75	134	148.5
Weight (kg)	33.69	2.61	32.35	32	38.2
BMI (kg/cm^2)	17.6	0.59	17.46	16.98	18.91

ference was not statistically different (p=0.07, adjusted p=0.17), it is worth noting.

Our second hypothesis is that Kinovea based FMS will achieve a higher degree of precision than standard FMS test. To that effect, we tested for equality of variances in correlated samples with a test that is often used in biomedical research as a simple test for comparing precision of two instruments that both measured the same population[9]. We are primarily interested in the variance of the composite FMS score and our test concluded that variances were equal (p=0.07, adjusted p=0.39). However, due to low sample size, out study is probably underpowered so considering our results, general recommendation would be to conduct another study with a larger sample size.

The review published in 2018[12] concludes that FMS is a popular but reliable method of assessment and evaluation can be consistently performed by examiners with different professional experience and education. We believe that the inclusion of the off-site scoring could improve assessment with regard to on-site mode due to

Table 3. **Average FMS values per test measured with and without Kinovea software**

	FMS 1		FMS 2		FMS 3		FMS 4		FMS 5		FMS 6		FMS 7		FMS Σ	
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*
FMS	2.2	0.6	2.2	0.4	2.7	0.5	1.1	0.3	2.9	0.3	2.5	0.8	1.9	0.3	15.5	1.8
FMS-K	1.2	0.4	2.4	0.5	2.4	0.5	1.1	0.3	2.9	0.3	2.3	0.7	1.9	0.3	14.2	0.9

Table 4. **Results of Wilcoxon Signed Rank Test for FMS scores versus FMS-K scores**

	FMS Median	FMS – K Median	V	*p*	Adjusted *p*
FMS 1	2	1	36	< 0.01	0.04*
FMS 2	2	2	7	0.41	0.59
FMS 3	3	2	6	0.08	0.17
FMS 5	3	3	1.5	0.99	0.99
FMS 6	3	2	7.5	0.32	0.48
FMS 7	2	2	0	0.99	0.99
FMS Σ	15.5	14	37.5	0.07	0.17

Note: FMS – standard FMS score; FMS-K – Kinovea enhanced FMS scores

Table 5. **Paired Pitman-Morgan test for equality of variances of FMS scores versus FMS-K scores**

	FMS SD^2	FMS – K SD^2	t	*p*	Adjusted *p*
FMS 1	0.18	0.40	1.22	0.26	0.77
FMS 2	0.27	0.18	-0.63	0.54	0.82
FMS 3	0.27	0.23	-0.22	0.83	0.99
FMS 5	0.10	0.10	0.00	0.99	0.99
FMS 6	0.46	0.72	0.89	0.40	0.79
FMS 7	0.10	0.10	0.00	0.99	0.99
FMS Σ	0.84	0.39	2.13	0.07	0.39

the possibility of more consistent results, i.e. within and between assessors.

uchna et al., based on their systematic review with meta-analysis, discuss that the examiner's experience might play a role in the reliability of the FMS assessment[13]. Aforementioned authors conclude that when implementing the FMS system in clinical practice, there is a need for further examination options to improve the reliability in novice practitioners in order to enhance the reliability of this technique between the assessors with different levels of experience for optimal implementation in practice.

In order to reduce the disadvantages of evaluation by practitioners with limited clinical experience the authors of this paper suggest performing post-assessment via video observation and objective software supported measurement, with the potential of standardization.

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PROCJENA DINAMIČKE POSTURE MLADIH GIMNASTIČARA: USPOREDBA METODA

Sažetak

Funkcionalna procjena pokreta (engl. *Functional Movement Screen* – FMS) je često korištena metoda za procjenu dinamičke posture sportaša. Upitna je valjanost i pouzdanost FMS-a kao metode za trijažu sportaša sklonih ozljedama, a jedna od glavnih kritika povezana je s objektivnošću same procjene. Ne postoje prethodna istraživanja koja su upotrebljavala računalni program Kinovea za preciznu procjenu s pomoću metode FMS.

U ovom istraživanju sudjelovalo je 10 selekcioniranih sportskih gimnastičara (četiri djevojčice i šest dječaka). S pomoću metode FMS vježbači su procijenjeni prema uobičajenom protokolu. Nakon standardne procjene, isti su sudionici ponovno procjenjivani s pomoću metode FMS, no preko računalnog programa za kinematičku analizu Kinovea.

S pomoću Wilcoxonova testa rangova uspoređeni su rezultati dobiveni primjenom dviju metoda FMS-a, standardne i Kinovea. S obzirom na rezultate, kod metode FMS-Kinovea pronađena je znatna razlika u testu 1 – Duboki čučanj. Medijan testa Duboki čučanj procijenjen standardnom metodom iznosio je 2 (srednja vrijednost iznosila je 2,1). Isti test procijenjen metodom FMS-Kinovea, imao je medijan 1 (srednja vrijednost bila je 1,2). Pitman-Morganov test za homogenost varijance primijenjen je za ispitivanje disperzije rezultata. Test nije pokazao nijednu razliku u homogenosti varijanci, no u sumiranom rezultatu testova *p*-vrijednost bila je blizu statističke značajnosti, što implicira postojanje razlike koju studija nije mogla otkriti zbog slabe snage istraživanja uzrokovane malim uzorkom.

Razlika u rezultatima testa Duboki čučanj pokazala se značajnom, što nije iznenađujuće, s obzirom na to da je procjena upravo tog testa najsloženija zbog velikog broja varijabli u dinamičkoj posturi koje procjenjivač mora uzeti u obzir.

Ključne riječi: dinamička postura, FMS, Kinovea, sportska gimnastika