Physical Therapy in Sport 28 (2017) 9–14

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Original Research

Construct validity and inter-rater reliability of the Gymnastic Functional Measurement Tool in the classification of female competitive gymnasts in Canada

Joseph Kaldas [a], Céline Bisson [a], Annie-Claude Hogue [a], Catherine Apinis [b], Djamal Berbiche [c], Nathaly Gaudreault [b, *]

[a] Physio Dynamik, 1200, Rome Boulevard, Local A, Brossard, Quebec, J4W 3H3, Canada
[b] University of Sherbrooke, School of Rehabilitation, Faculty of Medicine and Health Sciences, 3001, 12th Avenue North, Sherbrooke, Quebec, J1H 5N4, Canada
[c] Centre de recherche- Hôpital Charles LeMoyne, 150 Place Charles-LeMoyne – Bureau 200, Longueuil, Québec, J4K 0A8, Canada

ARTICLE INFO

Article history:
Received 4 November 2016
Received in revised form
7 July 2017
Accepted 28 July 2017

Keywords:
Gymnastics
Gymnastic functional measurement tool
Physical abilities
Validity

ABSTRACT

Objectives: To determine the construct validity and the inter-rater reliability of the Gymnastic Functional Measurement Tool (GFMT) within the parameters of the Canadian classification of female competitive gymnasts.
Design: Validity and Reliability study.
Setting: The GFMT was administered by evaluators who had no previous knowledge of the competing level of the gymnasts. To determine the construct validity, a multiple linear regression analysis was carried out between the GFMT scores and the gymnasts' competition level to obtain the coefficient of determination. To estimate the inter-rater reliability, gymnasts were simultaneously evaluated by two evaluators. Intraclass correlation coefficient (ICC) analysis was carried out for the individual score of each item as well as for the total score of the GFMT.
Participants: Ninety (90) female gymnasts aged between the ages of 8 and 18 years old.
Main outcome: GFMT total score and individual score of each item.
Results: The study demonstrated an excellent relationship between the total GFMT scores and the gymnasts' competition level ($r^2 = 0.97$). The inter-rater reliability analysis of the GFMT total score was excellent with an ICC of 0.98.
Conclusion: Construct validity and inter-rater reliability of the GFMT in the classification of female competitive gymnasts in Canada has been demonstrated.

1. Introduction

There are more than 200 000 registered members of the Canadian Gymnastics Federation (Gymnastics Canada [Internet], 2011). In the last two decades, the number of children involved in gymnastics has increased significantly (Cohen & Sala, 2010). Moreover, competition at the international level takes place at a young age. Gymnasts submit their bodies to hundreds of thousands of repetitions of their training elements each year (Caine, Cochrane, Caine, & Zemper, 1989; Sands, Henschen, & Shultz, 1989), with training loads reaching forces ranging from 5 to 17.5 times their bodyweight (Caine & Linder, 1985; McNitt-Gray, Munkasy, & Welch, 1994). Such high training loads combined with the immaturity of their neuromusculoskeletal system (Micheli & Klein, 1991; Wilkins, 1980) and the complexity of the skills required may lead to repetitive strain injuries. This is particularly true if the gymnast's physical readiness or musculoskeletal maturity is below the demands required for her competitive level. Gymnastics is associated with a high injury rate, with an average of 4.8 injuries reported in emergency rooms per 1000 participants per year (Haycock &

* Corresponding author.
E-mail addresses: kaldas.pht@physiodynamik.com (J. Kaldas), bisson.pht@physiodynamik.com (C. Bisson), hogue.pht@physiodynamik.com (A.-C. Hogue), catherine.apinis@usherbrooke.ca (C. Apinis), djamal.berbiche@usherbrooke.ca (D. Berbiche), nathaly.gaudreault@usherbrooke.ca (N. Gaudreault).

http://dx.doi.org/10.1016/j.ptsp.2017.07.006
1466-853X/

Gillette, 1976; Singh, Smith, Fields, & McKenzie, 2008). Considering that gymnastics has one of the highest injury rates of all female sports (Caine, 2005; Sands, 2000; Singh et al., 2008), injury prevention should be the main focus for coaches, sports physical therapists and gymnastics federations. A measurement tool ensuring better management of female gymnasts by coaches and sports physical therapists could lead to better injury prevention.

In his article in 2000, Sands proposed measures to prevent injury in gymnastics (Sands, 2000). His recommendations are divided into several distinctive groups: gymnastics apparatus, gymnastics rules, training loads and training for children. Interventions pertaining to apparatus and rules must be considered by the federations in order to aid in reduction of injury rate. However, the focus for coaches and physical therapists' work is on training load while bearing in mind the musculoskeletal maturity in children. Sands states: "*Knowledge of the requisite physical and mental fitness levels for various skills can assist the coach and gymnast in determining skill readiness. (…) The optimum training of children is perhaps the most important problem facing contemporary gymnastics for women. A healthy balance between training, aspirations, talent, age-appropriate abilities, resources, economics and so forth is difficult to achieve in any group of children.*"(14 - p.367–368).

In gymnastics, training increases as a function of the gymnast's competitive level. The competitive categories in Canada differ from the classification system of other countries, namely the United States of America (USA), where categories range from *Level 1* to *Level 10* (USA Gymnastics [Internet], 2016). In Canada, gymnasts are organised into seven categories: *Provincial 1* to *Provincial 5 (P1 to P5)* followed by *National* and then *High Performance*, each of them categorized according to the athlete's age. The P1 category does not exist in the province where this study was conducted. Therefore, this research focuses on six categories of competition (Fédération de Gymnastique du Québec, 2015-2016). As seen in Table 1, each category is defined by the level of difficulty of the elements or skills to be executed by the athlete. The individual elements are rated according to their level of difficulty, ranging from A to G with element A being the easiest (Fédération Internationale de Gymnastique [Internet], 2015). Using the floor exercise as an example, a salto forward tucked has an A value, whereas a double salto forward tucked has an E value (Fédération Internationale de Gymnastique [Internet], 2015). As the level of competition increases, both the number of required elements and their level of difficulty increase. At the National and High Performance level, the requirements are defined by the International Gymnastics Federation. The more a gymnast's competitive level increases, the more she will require fine-tuned physical abilities to execute her combinations of complex elements. This progression of required physical abilities underlines the importance of classifying gymnasts into categories that not only keep pace with their ability to perform elements and combinations, but also respect their physical abilities and physical maturity. A valid and reliable sport specific measurement tool would be useful to help identify weaknesses in gymnasts' physical abilities and related deficits that may predispose to future injury.

1.1. The gymnastic functional measurement tool

The Gymnastic Functional Measurement Tool (GFMT) was developed by Mark D. Sleeper, a physical therapist working with gymnastics, to assess a female gymnast's overall fitness level (Sleeper & Casey, 2010; Sleeper, Kenyon, & Casey, 2012). The GFMT is sport specific and produces an objective measurement of the gymnast's physical abilities without explicitly measuring gymnastic skills (Sleeper & Casey, 2010; Sleeper et al., 2012). It can be used to assess beginner gymnasts as well as elite competitive athletes. In order to assess muscular strength, endurance, flexibility, agility, coordination and balance, Sleeper designed a test composed of ten items, each of which bestows a point value (0–10) related the gymnast's performance. The GFMT items are as follows: *Rope Climb Test* (Belinda, Gabbe, Finch, Wajswelner, & Bennell, 2004); *Jump Test* (Brooks, Schiff, & Rivara, 2009); *Hanging Pikes Test* (Caine, 2005); *Shoulder Flexibility Test* (Caine et al., 1989); *Agility Test* (Caine & Linder, 1985); *Over-grip Pull-up Test* (Cohen & Sala, 2010); *Splits Tests* (Fédération Internationale de Gymnastique [Internet], 2015); *Push-up Test* (Gymnastics Canada [Internet], 2011); *20-Yard Sprint Test* (Haycock & Gillette, 1976) and *Handstand Test* (McNitt-Gray et al., 1994) (Sleeper et al., 2012). Each item is assessed by an evaluator who will attribute the scores. The total score of the GFMT is calculated by adding the individual item scores, which are rated on a scale of 0–100 (Sleeper et al., 2012). The GFMT's construct validity has been demonstrated in the USA levels classification system by Sleeper (Sleeper & Casey, 2010; Sleeper et al., 2012), who reported a positive linear relationship between the GFMT total score and gymnasts' competitive level ($r^2 = 0.602$, $p < 0.0001$) (Sleeper et al., 2012). The GFMT total score and individual component scores showed good test-retest reliability (Intraclass correlation coefficient (ICC) = 0.97 for total score and ICC ranging from 0.80 to 0.92 for individual components) (Sleeper et al., 2012). Inter-rater reliability has not yet been established. In Canada, however, the categorisation of competitive gymnasts differs from the level system in the USA (Fédération de Gymnastique du Québec, 2015-2016; USA Gymnastics [Internet], 2016). Utilisation of the GFMT by Canadian coaches and sports physical therapists requires that validity and reliability of the GMFT be investigated.

1.2. Purpose/hypothesis

The purpose of this study is to assess 1) the construct validity and 2) the inter-rater reliability of the GFMT within the parameters of the Canadian classification of female competitive gymnasts. The hypotheses are 1) that there is a positive relationship between a female gymnast's GFMT total score and her competitive level in the Canadian classification of competitive gymnasts (coefficient of determination $r^2 > 0.6$) and 2) that the inter-rater reliability will reach a satisfactory level (Intraclass correlation coefficient ICC > 0.6. (Hinkle, Wiersma, & Jurs, 2003; Mukaka, 2012).

Table 1
Classification of female competitive gymnasts in Canada.

All age categories Argo to Senior 8 years old and above	Provincial				National	
	Provincial 2	Provincial 3	Provincial 4	Provincial 5	National	High performance
Number of Required Element	6 elements	6 elements	6 elements	8 elements	IGF rules	IGF rules
Level of Difficulty	A allowed	A-B allowed	A-B-C allowed	A-B-C-D allowed	IGF rules	IGF rules

2. Methods

2.1. Population

Ninety five (95) female gymnasts were recruited in this study. The subjects were aged between the ages of 8 and 18 years old. Inclusion criteria were: 1) a female gymnast 8 years old and older, 2) competing in categories from P2 to High Performance. Exclusion criteria included the presence of any condition limiting the gymnast's ability to train or compete without restriction. The eligibility criteria are summarized in Table 2. The target population was composed of a minimum of ten gymnasts per competitive category. The sample size is justified by the fact that the GFMT consists of ten tests and, according to Tabachnick (Tabachnick, 2007), between 5 and 10 participants per test (5:1) is enough to provide reliable correlation estimates. Of the 95 subjects recruited for this study, 90 subjects participated. Five of the recruited subjects were excluded from the study. Exclusions were due to recent injury ($n = 3$), not completing the test ($n = 1$) or not participating in the competitive circuit ranging from P2 to High Performance ($n = 1$).

2.2. Recruitment procedures

Ethical approval for this research was obtained from the associated University Ethical Review Committee. Head coaches of several gymnastics clubs were then contacted. Clubs were chosen for their convenient location. Subsequently, coaches were asked to allow the research team to access each training gym and meet the gymnasts and their parents to explain the research protocol. A brochure describing the project and providing contact information for questions was also given to both the gymnast and her parent(s). For each gymnast willing to participate, the research team collected the pre-evaluation questionnaire, including questions about inclusion and exclusion criteria, and the consent form signed by the gymnast and the parent.

2.3. Data collection

Before starting the data collection, all gyms were visited by two of the four evaluators to ensure that facilities could accommodate the GFMT. These evaluators are physical therapists and ex-gymnasts who were competing at highly competitive levels. They familiarized themselves with the GFMT prior to the evaluation of the gymnasts and performed a trial run. During this trial run, the physical therapists completed the tasks required for each station to be sure that the settings were appropriate for testing (i.e. spatial organization of the material and of the stations one related to the other, position of the evaluator, to optimize the logistic of the data collection). It must be noted that the GFMT was conducted in French and all related procedures, documents and consent forms were produced in French, so as to facilitate recruitment of gymnasts.

2.3.1. Construct validity

The data collection was conducted on site at the various gymnasts' training facilities and participants did not have prior knowledge or exposure to the GFMT tasks. For each evaluation session, preparation of the different stations was made prior to the arrival of the gymnasts. Each participant was met individually to ensure that the consent form was duly completed and that the gymnast met the criteria for the study. Gymnasts were then randomly assigned a number that was written on their calf. This number matched the number written on the gymnast's general information sheet and the evaluator's scoring sheet which were anonymized. Before beginning the assessment of the GFMT, all gymnasts performed their regular warm up routine. The GFMT was then administered to groups of eight to twelve gymnasts of different categories at a time. All groups were given a standardized explanation of each task of the GFMT by the evaluator before each station. Each participant was evaluated by one of the 4 evaluators for all items of the GFMT. The evaluators were two physical therapists specialized in gymnastics (see above) and two physical therapy students. The evaluators had no previous knowledge of the competing level of gymnasts. Stations were executed following the order established in the GFMT and a minimum of 5 min of rest was given to the gymnasts between each station. The evaluators independently recorded raw data for each item of the GFMT according to the GFMT scoring system.

2.3.2. Inter-rater reliability

The first 33 gymnasts of the 90 participating gymnasts were independently evaluated by two evaluators in an effort to measure the inter-rater reliability of the GFMT. For each participant, the two evaluators assessed each item of the GFMT simultaneously on a separate scoring form. The evaluators were blinded from each other's scores and did not communicate with each other during the scoring process. Confirmation of the inter-rater reliability allowed us to involve four evaluators to assess the remaining of the gymnasts sample to study the construct validity.

2.4. Statistical analysis

In order to determine the construct validity of the GFMT and its individual tests in relation to the Canadian classification of competitive gymnasts, a multiple linear regression analysis was carried out between the total GFMT scores in addition to individual item scores and the gymnasts' competition level to obtain the coefficient of determination r^2 for each. The authors chose to use a multiple linear regression model in order to analyse the continuous response variable (the scores) and to examine the relationship between the scores and the principal independent variable (the gymnasts' competition level). A satisfactory level was set at $r^2 > 0.6$ (Hinkle et al., 2003; Mukaka, 2012). To estimate the inter-rater reliability of the GFMT, Intraclass correlation coefficient (ICC) analysis was carried out for the individual score of each item and for the total score of the GFMT. The level of acceptable correlation was set at ICC >0.6 (Hinkle et al., 2003; Mukaka, 2012). The level of significance was set at $p < 0.05$.

3. Results

The multiple linear regression analysis demonstrated an

Table 2
Eligibility criteria.

Inclusion	Exclusion
• Female • 8–18 years old • Gymnast competing in categories from P2 to High Performance	• Any condition limiting the gymnast's ability to train or compete without restriction

excellent relationship between the total GFMT scores and the gymnasts' competition level according to the Canadian classification ($r^2 = 0.97$), as seen in Fig. 1. This confirms the hypothesis that the GFMT is a useful tool for the assessment of gymnasts within the Canadian classification system. Upon further analysis, a statistically significant difference between the GFMT total scores was found for the P2 to P5 categories ($p < 0.05$). The total scores for the P5, National and High Performance categories were not statistically different from one another (p values varying from 0.29 to 0.57). Mean GFMT total scores as well as mean GFMT individual item scores are presented in Table 3.

The relationship between individual item scores and the gymnasts' competition level varied from poor to excellent ($r^2 = 0.01–0.96$), as seen in Table 3. All relationships were statistically significant ($p < 0.05$). The Shoulder Flexibility Test (Caine et al., 1989) is the only individual item that showed a poor relationship with the competition level, with r^2 value of 0.01. The Splits Tests (Fédération Internationale de Gymnastique [Internet], 2015) showed a moderate relationship with the competition level ($r^2 = 0.53$). The other eight tests showed good to excellent relationships with the competition level ($r^2 = 0.65–0.96$).

The overall reliability analysis of the GFMT total score found an excellent inter-rater reliability (ICC = 0.98; standard error of measurement (SEM) with 95% confidence intervals (CI) [0.96 to 0.99]). Individual item reliability analysis of the GFMT showed also good to excellent inter-rater reliability (ICC = 0.68–1.00), as presented in Fig. 2. Only the 20-Yard Sprint Test (Haycock & Gillette, 1976) showed inter-rater reliability close to the inferior limit of acceptable correlation (ICC = 0.68). All other nine individual items found excellent inter-rater reliability (ICC = 0.91–1.00).

4. Discussion

Physical therapists monitor musculoskeletal readiness and physical abilities in the treatment and return to sport of injured gymnasts. These same attributes are also important when considering injury prevention in gymnastics. The importance of using sport specific tools to evaluate physical abilities has been reported in other domains (Belinda et al., 2004; Brooks et al., 2009). The GFMT is the first field measurement tool developed specifically to evaluate the physical abilities necessary for success in competitive gymnastics. It has the advantage of being easy to use by gymnastics coaches and physical therapists, and it requires simple equipment available in most gymnastics gyms. The relationship between USA gymnastics competition levels and the GFMT total scores has already been demonstrated in the past (Sleeper et al., 2012).

In this study, the relationship between the GFMT total scores and the competition levels was demonstrated according to the Canadian classification of competitive gymnasts. These findings provide additional support for the construct validity of the GFMT. When closely examining the results, the difference between the total GFMT score of the different categories was statistically significant for the P2 to P5 categories. Above the P5 category there is less of a difference between the total GFMT score of each category. As such, it is possible that at a higher level of gymnastics only a small variation in physical ability accounts for the difference between competitive categories. It may not vary enough to significantly change the GFMT total scores in the competitive levels above the P5 category. This leads the authors to believe that other specific tests may be required to improve the GFMT ability to accurately measure the physical abilities of higher level gymnasts. Therefore, it would be interesting to consider tests such as active flexibility and proprioception. These are examples of tasks that require a high level of motor control which could be a distinguishing component of physical abilities of high level gymnasts.

The analysis of the relationship between the GFMT individual item scores and the gymnasts' competition level reveals that almost all items relate to the gymnasts' competition level. These findings differ from those of Sleeper's study (Sleeper et al., 2012). The multiple linear regression model used in this study analyzes mean scores for each competition level in comparison to Sleeper's simple regression model which analyzes individual scores for each gymnast. The authors chose the multiple linear regression model to allow a stronger analysis of the relationship between a continuous

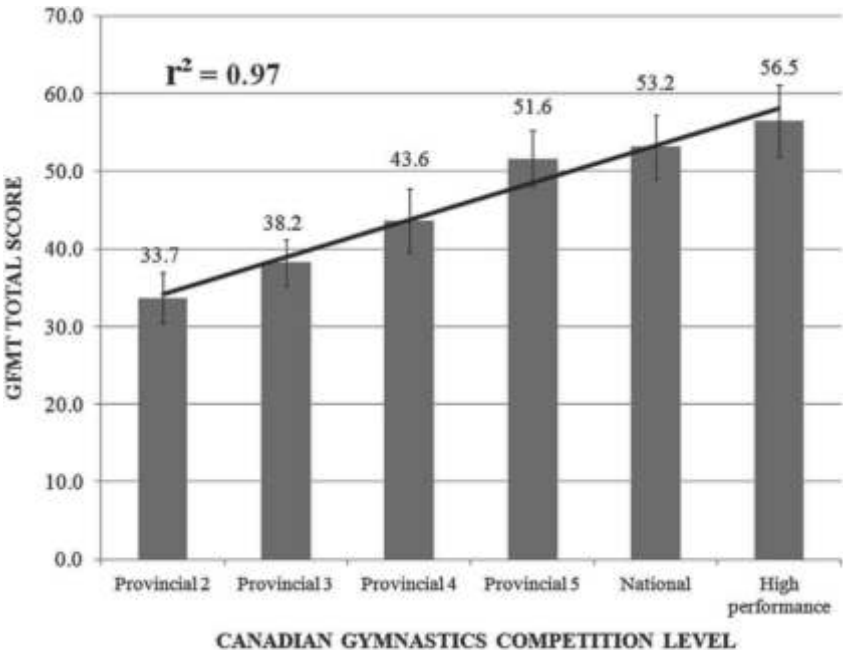

Fig. 1. GFMT total scores.
Relationship between the total GFMT scores and the gymnastics competition levels according to the Canadian classification with error bars representing 95% confidence intervals.

Table 3
Mean GFMT scores for each competition level.

GFMT items / Competition Level	1 Rope	2 Jump	3 Pikes	4 Shoulder	5 Agility Sprint	6 Pull-up	7 Splits	8 Push-up	9 20 yard sprint	10 Handstand	Total Score [95% CI]	
Provincial 2	3.51	2.83	3.36	3.67	4.20	1.78	4.62	2.41	5.88	1.41	33.7 [30.4 - 36.9]	p = 0.044 *
Provincial 3	5.18	3.50	3.86	2.59	4.50	3.18	4.05	2.86	6.36	2.14	38.2 [35.2 - 41.3]	p = 0.039 *
Provincial 4	5.12	3.46	5.12	3.79	5.62	3.21	4.04	3.12	6.20	3.87	43.6 [39.5 - 47.6]	p = 0.004 *
Provincial 5	7.45	4.58	6.85	2.78	5.78	5.58	5.58	4.31	6.64	2.04	51.6 [48.0 - 55.2]	p = 0.574
National	6.31	4.81	6.64	3.64	6.22	4.56	5.39	4.56	6.89	4.14	53.2 [49.1 - 57.2]	p = 0.286
High performance	7.93	4.73	6.73	3.03	6.73	5.53	5.43	4.53	7.33	4.53	56.5 [51.8 - 61.1]	
r^2	0.82	0.88	0.86	0.01	0.96	0.80	0.52	0.91	0.92	0.65	0.97	
ICC	0.92	0.98	0.94	0.99	0.95	0.98	0.97	0.91	0.68	1.00	0.98	

* Corresponds to a statistically significant difference between the GFMT total scores for the P2 to P5 categories ($p < 0.05$).

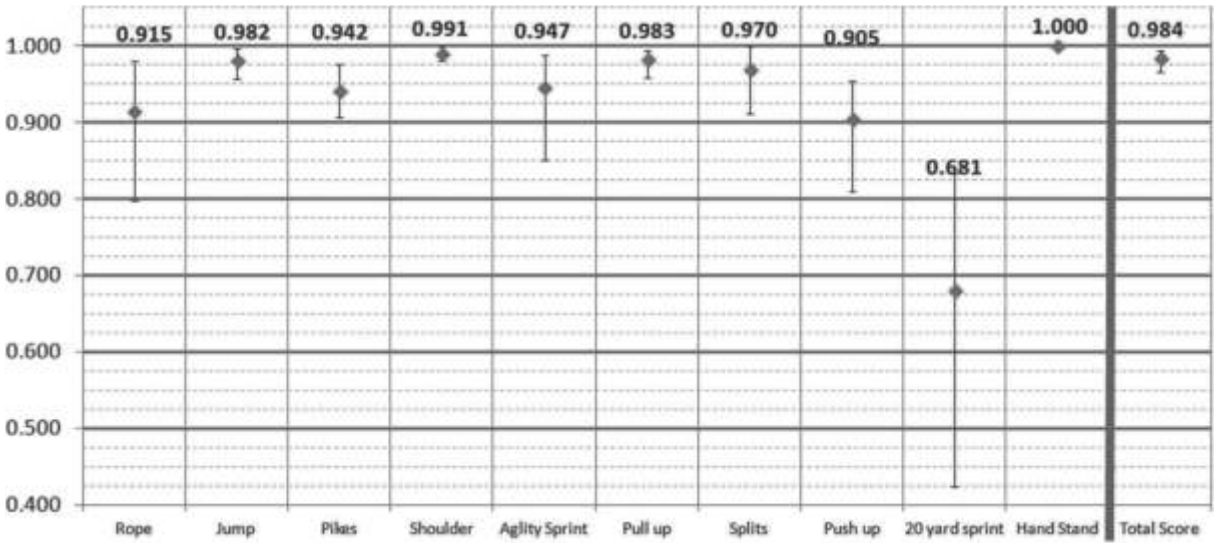

Fig. 2. Inter-rater reliability.
Intraclass correlation coefficients (ICC) for inter-rater reliability with error bars representing the standard error of measurement with 95% confidence intervals.

variable (the score) and a non-continuous variable (gymnasts' competition level). The authors found that the following eight individual items have a good relationship with the competition level: Rope Climb (Belinda et al., 2004), Jump Test (Brooks et al., 2009), Hanging Pikes (Caine, 2005), Agility (Caine & Linder, 1985), Overgrip Pull-up (Cohen & Sala, 2010), Push-up (Gymnastics Canada [Internet], 2011), 20-Yard Sprint Test (Haycock & Gillette, 1976) and Handstand (McNitt-Gray et al., 1994). The Shoulder Flexibility Test (Caine et al., 1989) is the only GFMT item that shows a poor relationship with the competition level. In his study, Sleeper observed similar results regarding the Shoulder Flexibility Test. Contrary to Sleeper's belief, the authors of this study question the relevance of maintaining the Shoulder Flexibility Test as a part of the GFMT individual items. This does not mean that shoulder flexibility is not an important physical ability in gymnastics, but it may require a different test to be evaluated.

Since the GFMT is designed as a field-test that could be administered by gymnastics coaches as well as many other professionals, the analysis of inter-rater reliability was essential. This research is the first to establish the GFMT inter-rater reliability. In this study, two of the evaluators were physical therapy students, without any prior knowledge in gymnastics. This demonstrated that other professionals could administer the GFMT in the absence of specific knowledge of gymnastics. The evaluators measured all the movements in real time without the use of special equipment such as video cameras. The results showed an excellent level of inter-rater reliability according to the total score of the GFMT as well as the individual items scores. These findings demonstrate that criteria for evaluating the different GFMT items are significantly objective. The use of a trial run before the beginning of the study may have favored the inter-rater reliability. The Sprint Test is the only individual item that demonstrated a moderate inter-rater reliability. The authors explain this result by the loss of precision due to the use of a manual chronometer combined with the very small time intervals (0.15 s) that differentiate each possible score in the rating scale of the Sprint Test. The margin of error due to the evaluator's reaction time is important considering that the Sprint Test is done on a short distance (20 yards). Despite this shortcoming, the reliability analysis of the Sprint Test found that the ICC was slightly over the level of acceptable correlation (ICC = 0.68;

SEM with 95% CI [0.425 to 0.833]). In addition, the relationship between the 20-Yard Sprint Test score and the gymnasts' competition level was demonstrated earlier on by an excellent coefficient of determination ($r^2 = 0.92$). Therefore, the authors believe that the Sprint Test should remain part of the GFMT.

Limiting factors were identified in this study. On the field, the GFMT will be mainly used by gymnastics coaches. However, in this study no coaches were recruited as evaluators. The authors believe that the use of physical therapists highly specialized in gymnastics as well as physical therapy students with no background in gymnastics as evaluators ensures the generalizability of this tool for coaches and healthcare professionals working with gymnasts. The authors also recognize the fact that, since the data collection was conducted in groups of eight to twelve gymnasts, it may have encouraged a competition effect between the gymnasts, heightening their performance and leading to a possible overestimation of the scores. However, since the GFMT is a field-test, the data collection in this study reflects the real environment in which the test can be conducted. The results should relate to all categories of the classification of female competitive gymnasts in Canada with the possible exception for the Provincial 1 category, since it is not represented in our province. However, the authors have no reason to believe that gymnast living in Québec would be any different to gymnast living in the rest of the country or anywhere else in the world. Québec only distinguishes itself by not having the P1 level.

Further studies could explore the possibility of adding small modifications to the GFMT to improve the tool, such as a different way to measure shoulder flexibility. It would also be interesting to consider new tests that measure abilities such as active flexibility and proprioception for higher level gymnasts. The next step for research is establishing the correlation between physical abilities and injury rates in gymnastics. It would be interesting to pursue whether gymnasts scoring lower on the GFMT within a given category have a higher risk of injury. Ultimately, the GFMT may become an objective tool for coaches and healthcare professionals to evaluate an athlete's recovery timetable after injury and progression through the competitive categories. It would help to reduce the risk of injury and allow for gymnasts to be more physically prepared to meet the high requirements of the sport.

4.1. Knowledge transfer

This project is a good example of knowledge transfer between the clinical field, the gymnastics community (clubs) and a university research setting. It arose from actual clinical dilemmas experienced by physical therapists and coaches who work closely with young injured gymnasts and face the issue of their physical readiness.

5. Conclusion

This study demonstrated the construct validity of the GFMT in the classification of female competitive gymnasts in Canada and it is the first to document the inter-rater reliability of the GFMT.

Ethical approval

This study was approved by the University Ethical Review Committee.

Funding

This study was supported by a grant from the *Ordre professionnel de la physiothérapie du Québec* (OPPQ).

Conflict of interest

None declared.

Acknowledgements

The authors would like to acknowledge the contribution of the following University of Sherbrooke physiotherapy students: *Mathieu Savard, Timothy Ho, Andreanne Belley-Houle, Julie Charbonneau and Jean-Pascal Beauchamp.*

The authors would also like to recognize the financial contribution of the Quebec Order of Physiotherapy (*Ordre professionnel de la physiothérapie du Québec*) that permitted the completion of this study.

References

Belinda, J., Gabbe, B. J., Finch, C. F., Wajswelner, H., & Bennell, K. L. (2004). Predictors of lower extremity injuries at the community level of Australian football. *Clinical Journal of Sport Medicine, 14*(2), 56.

Brooks, M. A., Schiff, M. A., & Rivara, F. P. (2009). Identifying previous sports injury among high school athletes. *Clinical Pediatrics, 48*(5), 548–550.

Caine, D. (2005). Gymnastic injuries. *Medicine and Sport Science, 48*, 18–58.

Caine, D., Cochrane, B., Caine, C., & Zemper, E. (1989). An epidemiologic investigation of injuries affecting young competitive female gymnasts. *The American Journal of Sports Medicine, 17*(6), 811–820.

Caine, D. J., & Linder, K. J. C. (1985). Overuse injuries of growing bones: The young female gymnast at risk? *The Physician and Sportsmedicine, 13*(12), 51–64.

Cohen, E., & Sala, D. A. (2010). Rehabilitation of pediatric musculoskeletal sport-related injuries: A review of the literature. *European Journal of Physical and Rehabilitation Medicine, 46*, 1–14.

Fédération Internationale de Gymnastique [Internet]. (2015). *Code of points - women's artistic gymnastics - "01-1 WAG CoP 2013-2016 (English).pdf"*, 2016 Jan 5 http://www.fig-gymnastics.com/publicdir/rules/files/wag/WAG%20CoP%202013-2016%20June%202015-E.pdf.

Fédération de Gymnastique du Québec. (Novembre 2015-2016 Jan 5). *Gymnastique Québec [Internet]. Programme provincial Quebec 2015-2016, tableaux principaux.* version-2-novembre-2015-hl.pdf Version 2.0. http://www.gymqc.ca/static/uploaded/Files/Documents/2015-2016-GAF-PPQC-version-2-novembre-2015-hl.pdf.

Gymnastics Canada [Internet]. (2011 Jan 3). *Our Profil. GymCan*. http://www.gymcan.org/site/gym_overview.php.

Haycock, C. E., & Gillette, J. V. (1976). Susceptibility of women athletes to injury. *The Journal of the American Medical Association, 236*, 163–165.

Hinkle, D. E., Wiersma, W., & Jurs, S. G. (2003). *Applied statistics for the behavioral sciences* (5th ed.).

McNitt-Gray, J. L., Munkasy, B. A., & Welch, M. (1994). External reaction forces experienced by the lower extremities during the take-off and landing of tumbling skills. *Technique, 14*(9), 10–16.

Micheli, L. J., & Klein, J. D. (1991). Sports injuries in children and adolescents. *Brit J Sport Med, 25*(1), 6–9.

Mukaka, M. M. (2012 Sep). Statistics corner: A guide to appropriate use of correlation coefficient in medical research. *Malawi Med J, 24*(3), 69–71. PMID: 23638278.

Sands, W. A. (2000 Nov). Injury prevention in women's gymnastics. *Sports Medicine, 30*(5), 359–373.

Sands, W. A., Henschen, K. P., & Shultz, B. B. (1989). National women's tracking program. *Technique, 9*, 14–19.

Singh, S., Smith, G. A., Fields, S. K., & McKenzie, L. B. (2008 Apr). Gymnastics-related injuries to children treated in emergency departments in the United States, 1990–2005. *Pediatrics, 121*(4), e954–e960.

Sleeper, M. D., & Casey, E. (2010 Jan). The gymnastics functional measurement tool: A valid way of measuring gymnastics physical abilities. Platform presentation at the APTA Combined Sections Meeting. San Diego, CA 2010. Abstract published in: *Journal of Orthopaedic & Sports Physical Therapy, 40*(1), A20.

Sleeper, M. D., Kenyon, L. K., & Casey, E. (2012 Apr). Measuring fitness in female gymnasts: The gymnastics functional measurement tool. *IJSPT, 7*(2), 124–133.

Tabachnick, B. G. (2007). *Using multivariate statistics* (5th ed.) Boston.

USA Gymnastics [Internet]. (2016 Jan 5). *2015-2016 women's program rules and policies, governing competitors and competitions sanctioned by the national women's program committee*. https://usagym.org/PDFs/Women/Rules/Rules%20and%20Policies/2015_2016_w_rulespolicies_0105.pdf.

Wilkins, K. E. (1980). The uniqueness of the young athlete: Musculoskeletal injuries. *The American Journal of Sports Medicine, 8*(5), 377–382.