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ABSTRACT

Background: Women's gymnastics ranks second highest in collegiate sports for injuries. The gymSAFE Movement Screen (GMS) is the first screening application to identify areas associated with mechanisms of injury in gymnastics. Purpose: Investigate reliability of GMS scores between two physical therapists who varied in experience with gymnastics. **Methods:** 25 female gymnasts, between 5-16 years of age, were screened by two physical therapists. Percent agreement and intraclass correlation coefficients (ICCs) of scores were analyzed. **Findings:** ICC for total scores was .71 (95% CI (p<.002) for the first measurement and 0.51 (p <.043) for the second. Percent agreement fundamental gymnastic movements items ranged from 42.4% to 77.6%, and 84.6% to 92.3% for the strength and flexibility items. **Clinical Relevance:** A universal screen can assist in interdisciplinary care for female gymnasts. **Conclusions:** Overall, the physical therapists were strongly comparable especially in areas of strength and flexibility. Training for concordance appears necessary for fundamental gymnastics movement subscale because agreement was more variable.

Key Words: application, assessment, prevention, risk score

BACKGROUND

Certain sports are found to have higher severe injury rates, as well as specific musculoskeletal injuries common to that sport.[1,2] Women's gymnastics ranks second highest in National Collegiate Athletics Association sports for severe injuries (defined as acute in nature, happen during competition or practice, require immediate medical attention, and result in at least 3 weeks break from participation or a premature end to their season).[1] In addition to the high severe injury rates, female gymnasts also have high non-traumatic injury rates such as "any damaged body part that interferes with training" and repetitive stress injuries.[2] It has been found female gymnasts train 71% of the time with an injury,[2] often with 45% of these injuries lingering at 38.5 months follow-up.[3] Developing a way to prevent the high injury rates experienced by female gymnasts is a priority to families, coaches, and the providers who care for them.

Similar to developing sport specific training programs for optimal performance, developing sport specific injury prevention screens can potentially assist coaches and providers in the prevention and treatment of musculoskeletal injuries common to that sport. While the Functional Movement Screen (FMS) and Selective Functional Movement Assessment (SFMA) have both been used to help identify areas prone to injury in various sports[4–8], neither are sport specific and vary in their accuracy in predicting injury risk.[4–8] A sport specific screening tool that is valid and reliable could potentially reduce the rates of common injuries experienced in gymnastics, and improve the ability of athletes to train and compete without symptoms.

The Gym Specific Acrobatic Functional Evaluation (gymSAFE) Movement Screen is the first assessment tool to specifically focus on identifying and addressing key common movement faults associated with mechanisms of injury in gymnastics. Using an application (app) to input the movement screen scores, the app summarizes the data and provides a "needs attention at risk" score of each body part. The score is provided to the gymnasts, parents, and coaches to help tailor the gymnasts' training program to prevent injury to the proposed "needs attention" body part. In addition, the gymnast has a quantifiable score that is described in a universal language of strength, range of motion, and foundational movements that all healthcare providers, even those who are not familiar with gymnasts, can understand. This provides efficiency and a cohesive treatment plan among all the providers for the gymnast. Once the score has been reviewed, the gymnasts are taught a gymnastics-specific exercise program designed by a physical therapist with a deep understanding of the needs of the sport.

Another screening tool that is specific to gymnastics is the Gymnastics Functional Measurement Tool (GFMT). This screen focuses on overall fitness (power, speed, flexibility, strength, muscular endurance, and balance) of the gymnast and provides insight to the gymnasts overall total physical fitness and physical state.[9] The gymSAFE Movement Screen provides additional gymnastics-specific information by specifically identifying a competitive female athlete's individual area(s) movement faults that may make them prone to injury. Additionally, the gymSAFE Movement screen is followed by a treatment plan post screen. The gymSAFE Screen is tailored to address the most commonly injured areas of the body in female gymnasts: the foot, ankle, knee, shoulder, and back.[10,11] The purpose of this study is to determine the reliability between a physical therapist who is trained in gymnastics and a physical therapist who is not in administering the gymSAFE screen.

METHODS

Participants

The study was approved through the Notre Dame de Namur University and University of the Pacific Institutional Review Boards. Signed informed consent and assent was provided by each parent and participant, respectively, prior to participating in the study. Study participants needed to be between the ages of 5 and 18 years of age, currently practice with a competitive gymnastics team, and speak and understand English. While the gymSAFE screen was designed with female gymnasts in mind, male gymnasts were not excluded in participating. All participants volunteered and could stop participation at any time during the study. Participants were able to opt out of any assessment that they think would cause pain.

Recruiting for the study took place at local gyms by flyers and on social media sites. Coaches were asked if they were interested in having their gymnasts assessed for injuries using the gymSAFE Screen. If the coaches said yes, then each participant and their parents were asked if they would like to participate in the study. Once consent and assent were received, the parent was emailed the gymSAFE questionnaires regarding the child's years of experience in gymnastics, history of injuries, and the dates and locations of the screening sessions.

Tests and measures

The gymSAFE screen is a 15 min screen designed to be a concise, yet thorough examination of competitive gymnasts' musculoskeletal at-risk areas. The screen includes 3 major categories the gymnasts are assessed in: Flexibility/Range of Motion, Strength, and Fundamental Gymnastics Movements (FGMs) (**Table 1**).

Table 1. gymSAFE Assessment Categories and Tests

Flexibility/Range of Motion
- Elbow hyperextension
- Knee hyperextension
- Knee to wall
- Modified Thomas
- Wrists
- Prone knee bend
- Supine SLR
- Shoulder ER
- Shoulder IR

Strength
- Rotator Cuff ER
- Rotator Cuff IR
- Biceps
- Triceps
- Interscapular
- Quadriceps
- Hamstrings
- Gluteus Maximus
- Gastrocnemius
- Abs Leg Lowering

Fundamental Gymnastics Movements
- Single leg hop right
- Single leg hop left
- Plank and reach arms
- Plank and lift legs
- Drop jump right
- Drop jump left
- Back bend
- Tall kneeling

Abbreviation: SLR, straight leg raise; ER, external rotation; IR, internal rotation

Within the 3 major categories certain fundamental skills used in gymnastics are tested including balance, mobility of joints, manual muscle testing, flexibility testing, and sport specific functional tests. The battery of clinical and sport-specific tests for each category were designed by a gymnastics sport specific physical therapist and gymnastics coach; each with over 10 years' experience in the field. Using a password protected, cloud based, SaaS delivery model, computerized web application assessors enter the data as the participants are tested. An immediate report is then printed that summarizes the score the participant achieved in each of the areas of flexibility, strength, and movement. The report also includes a customized evaluation and recommended next steps from the assessor.

The gymSAFE application uses 3 subscales for assessment: flexibility, strength, and FGM. For the Flexibility and Strength score, assessors list either 2=Strong, 1=Weak, or 0=needs attention. For the FGM score, movements assessing balance, stability, and control are assessed with the assessors providing a score by checking or unchecking the box for whether the gymnast meets the desired form (**Figure 1**). The application then provides a summed score for each category of flexibility, strength, and fundamental gymnastic movements (FGM) as well as an overall score.

Study procedure

The study procedure began with concordance training between the 2 gymSAFE assessors. Two physical therapists assessed the gymnasts using the gymSAFE Screen. One of the physical therapists administering the screen was a gymSAFE staff member and the other was not. In the months prior to the study screening session the gymSAFE staff member trained the additional assessor how to perform the screen. Training consisted of the trainee reading the handbook of the screening components, watching the training videos of each test, meeting with the gymSAFE staff for hands on review of each test, practice assessing local volunteer gymnasts (**Figure 2**), and use of the application in real time; in total training took 4 hours.

Two screening sessions took place over 2 days. Each day of the study consisted of the 2 assessing physical therapists screening each gymnast 2 times, with a 30-minute break between each testing session. Before testing, the gymnasts were handed an iPad to watch and listen to the instructions on how to perform each of the FGMs. The gymnasts then performed the movement while the assessors

Figure 1. Sample Assessment of Functional Gymnastics Movements Single Leg Hop Right and Left

Single Leg Hop (Right)
- ✓ Stays within borders of box
- ✓ Foot-knee-hip alignment maintained
- ✓ Lands with good arch control
- ✓ Both hands stay on waist
- ✓ Pushes off foot
- ✓ Lands quietly (non stiff landing)
- ✓ Holds 5 seconds

Single Leg Hop (Left)
- ✓ Stays within borders of box
- ✓ Foot-knee-hip alignment maintained
- ✓ Lands with good arch control
- ✓ Both hands stay on waist
- ✓ Pushes off foot
- ✓ Lands quietly (non stiff landing)
- ✓ Holds 5 seconds

evaluated the movement. Participants could opt out of any movement they felt would produce pain. After each screen, scores were computed. The following day, participants received their scores and the researcher, who was affiliated with gymSAFE, reviewed the gymSAFE screen report with the participant, parent/guardian, and to their coach for training purposes. After the explanation of the report, the participants were given their exercise prescription and taught an exercise program, led by a physical therapist of the gymSAFE staff.

Data analysis

Primary analyses were limited to the female gymnast participants (n=25); as the gymSAFE screen was developed for evaluating female gymnasts' flexibility, strength, and FGMs. Percent agreement was used to describe the physical therapists comparability in assessment using the gymSAFE Screen. All data from the score sheets were pooled to compare the first assessor to the second using intraclass correlation coefficients (ICCs) and 95% confidence intervals. Statistical analyses were carried out using STATA 10 software (StataCorp LP, College Station, TX).

FINDINGS

Twenty-six (n=25 females) gymnasts

Figure 2. gymSAFE Assessment

Table 2. Percent Agreement Between the 2 Physical Therapists Scoring the gymSAFE Screen of Flexibility/Range of Motion

	Percent agreement between physical therapists for trial 1		Percent agreement between physical therapists for trial 2	
	Right	Left	Right	Left
Elbow hyperextension	64	60	77.6	76
Knee hyperextension	73.1	92.3	90	94
Knee to wall	69.2	76.9	79.5	88
Modified Thomas	73.1	50	68.6	68.6
Wrists	88.5	76.9	84.3	80.4
Prone knee bend	58.3	57.7	77.6	68.6
Supine SLR	50	65.4	70.6	64.7
Shoulder ER	76.9	73.1	94	86.3
Shoulder IR	76.9	80.8	84.3	96.1

Abbreviations: SLR, straight leg raise, ER, external rotation; IR, internal rotation

Table 3. Percent Agreement Between the 2 Physical Therapists Scoring the gymSAFE Screen of Strength

	Percent agreement between physical therapists for trial 1		Percent agreement between physical therapists for trial 2	
	Right	Left	Right	Left
Rotator Cuff ER	88.5	84.6	86.3	80.4
Rotator Cuff IR	88.5	76.	92.2	86.3
Biceps	76.9	76.9	88.2	82.4
Triceps	92.3	88.5	94.1	90.2
Interscapular	92	92.3	95.9	90.2
Quadriceps	96.2	94.6	90.2	92.2
Hamstrngs	90.8	65.4	78.4	74.5
Glluteus Maximus	50	76.9	68.6	68.6
Gastrocnemius	60	66.7	76.6	94.4
Leg Lowering	42.3		74	

Abbreviations: ER, external rotation; IR, internal rotation

participated in the study. The average age of the participating female gymnasts ranged between 5 and 16 years of age (average: 11.75 years), with a range of gymnastics levels. Percent agreements in flexibility/range of motion, strength, and FGMs portions of the screen, ranged from 50% to 96.1% (flexibility), 42.3% to 96.2% (strength), and 59% to 90.7% in the fundamental gymnastics movement category (**Tables 2-4**).

Percent agreements in "usual" physical therapy (meaning non-gymnastics specific physical therapy) flexibility/ROM, such as assessing knee hyperextension, shoulder internal/external rotation; the percent agreements ranged between 84.3% and 96.1%. In the "usual" physical therapy strength measures, such as assessing rotator cuff and tricep strength; percent agreements ranged between 84.6% and 92.3%. Whereas in the gymnastics specific flexibility/range of motion and strength measures, such as assessing abdominal strength by 2 leg lowering-a movement that most non-gymnasts do not perform daily; the physical therapists had lower agreements. Even so, by the second trial the percent agreement in such gymnastics specific flexibility/range of motion and strength scores increased by 31.7%.

Overall, the smallest difference between the physical therapist assessors in scoring were seen in the flexibility and strength categories (**Tables 2 and 3**). For example, in assessing left knee hyperextension at time 1 and 2, the physical therapists were 92.3% and 94% comparable (**Table 2**). In their assessment of left interscapular strength at time 1 and time 2, the physical therapists were 92.3% and 90.2% comparable (**Table 3**). In assessing right quadriceps strength at time 1 and time 2 the physical therapists were 96.2% and 90.2% comparable (**Table 3**). For the majority, the largest difference between the physical therapists were assessment in the FGMs. In the single leg hop (right) at time 1 and time 2, the physical therapists were 76.9% and 59% comparable (**Table 4**). However, within the tasks such as the plank and lift legs the assessors compared 90.7% at trial 2 (**Table 4**).

The ICC for comparing overall total scores between the two physical therapists for the first screen was .71 (95% CI [0.4,0.9]); p<.002 (**Table 5**). The ICC for the second screen was 0.51 (95% CI [-0.1,0.8]); p <.04 (**Table 5**).

CLINICAL RELEVANCE

Overall, the two physical therapists had strong agreement in their total gymSAFE screen scores. It was interesting to note that while the reliability between the physical therapists ranged and decreased at the second screen (to "moderate" vs "good" at screen one), overall, their percent agreements

Table 4. Percent Agreement Between the 2 Physical Therapists Scoring the gymSAFE Screen of Fundamental Gymnastics Movements

	Percent agreement between physical therapists for trial 1	Percent agreement between physical therapists for trial 2
Single leg hop right	76.9	59
Single leg hop left	72.5	66.7
Plank and reach arms	69.3	74.1
Plank and lift arms	69.9	90.7
Drop jump right	75.4	75.9
Drop jump left	71.5	68.5
Back bend	82.9	88.9
Tall kneeling	84.6	75.9

Table 5. Intraclass Correlation Coefficients Between Assessors at Screen 1 and Screen 2, with 95% CI

1st Screen Average ICC (95% CI)	2nd Screen Average ICC (95% CI)
0.70 (95% CI, 0.4, 0.9)	0.51 (95% CI -0.1, 0.8)
p<0.002	p< 0.043

increased. The two categories the physical therapists were most comparable in were the Flexibility and Strength categories and were less comparable in the FGMs. The gymSAFE Screen uses common strength and flexibility measures that all physical therapists are trained in; whereas the FGMs were specifically chosen for their basis in gymnastics, which many physical therapists may be unfamiliar with. In addition, even within the "usual" physical therapist measures of Flexibility and Strength-while some of the components are common to physical therapy knowledge (prone knee bend), the difference lies in what a prone knee bend looks like in a gymnast vs in a non-gymnast, and how this is assessed by the gymSAFE protocol; leaving room for differences in assessment. Another example of this difference is in how one physical therapist trained in orthopedics assesses abdominal strength can vary compared to how another physical therapist trained in gymnastics assesses abdominal strength; in particular, what qualifies as an indicator of "weakness" vs "strength" (example: Sahrmann Movement Screen vs Manual Muscle Testing). In the non-gymnastics patient population, the orthopedic physical therapists do not perform the gymnastics specific type of flexibility and strength exams or interventions. Therefore, making it less likely non-gymnastics orthopedic physical therapist would be familiar with the level of flexibility and strength seen in the gymnastics population. Thus, it is important that physical therapists are trained in each assessment of the gymSAFE screen, and understand the specific movements, to score the movements based on the gymSAFE classification, should they encounter gymnastic patients in their practice.

Limitations to this study include a small sample size of both patients and therapists. While the ranges in age and competitive level of the gymnasts provided good information on the overall reliability of the gymSAFE screen it is of interest to have larger sample sizes to determine reliability among specific age groups, competitive levels, and even specific gyms and teams. It is recommended that lead physical therapists, those trained in the gymSAFE screen, perform screenings and a consensus is achieved. From a recruitment perspective, due to the traveling schedule of the teams and that teams practice up to 20 hours a week, it was challenging to set up the assessment schedule. This meant participating in the screen required time for the gymnast to be away from practice. Future recruitment strategies can include the possibility of "whole team" recruitment or "whole gym" recruitment to minimize disruption in the practice schedule. It is of interest to have further reliability studies with coaches and other healthcare providers (medical doctors, athletic trainers, physician assistants, etc) which could assist with recruitment.

The gymSAFE screening application provides a sport specific screening tool that translates a gymnast's flexibility, strength, and overall sport specific functional movement information across disciplines. By efficiently and effectively translating this information; the care provided to female gymnasts is more complete amongst providers, coaches, and parents/guardians.

With reports of almost half of adolescent female gymnasts experiencing back pain[12] and overall high injury levels among all competitive levels, and rising medical costs; there is a call for consistent reporting methods.[13] This study demonstrates the gymSAFE application is reliable among two physical therapists, despite experience with gymnastics. The potential for reporting reliable and transferable information via gymSAFE application for both research and clinical care is of high value for the gymnastics field.

CONCLUSIONS

Overall, the physical therapists were strongly comparable in their gymSAFE scoring; especially in the areas of strength and flexibility. It is recommended that physical therapists interested in using the GMS, especially those not trained in gymnastics, be trained in how to assess; particularly in the fundamental gymnastics' movement category. Having a universal screen among providers can assist in better interdisciplinary care for our female gymnasts.

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