DOI: 10.7860/JCDR/2026/87940.23594

Original Article

Physiotherapy Section

Development, Reliability and Validity Testing of a Novel To and Fro Agility Test in School-going Children: A Cross-sectional Study

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ABSTRACT

Introduction: For children to participate in sports, physical education, and everyday functional tasks, agility is a crucial feature of motor fitness. Even though there are many agility evaluation methods available, many are constrained by space needs, complicated procedures, or decreased viability for school-age children. Thus, a straightforward, valid, and reliable field-based agility test that is appropriate for school-age children is required.

Aim: To develop a novel To and Fro Agility Test (TFAT) and to evaluate its content validity, test-retest reliability and criterion validity in school-going children aged 10 to 16 years.

Materials and Methods: A cross-sectional methodological study was conducted at MM International School Mullana, Ambala, Haryana, India between June 2025 to November 2025. The study consisted of 51 participants of which 25 were boys and 26 girls. Study followed COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) criteria. Six experts evaluated the content validity of the newly developed novel TFAT using a four-point Likert scale, and the Item Content Validity Index (I-CVI) was then calculated. By comparing TFAT performance with the 5-0-5 agility test, criterion validity was analysed. Intraclass Correlation Coefficient (ICC), Cronbach alpha, Standard Error mean (SEM), coefficient of variation, Smallest Worthwhile Change (SWC), Minimal Detectable Change (MDC), Bland-Altman analysis, regression analysis, Receiver Operating Characteristic (ROC) curve, sensitivity, specificity, and Area Under the Curve (AUC) were all included in the statistical analysis.

Results: The mean age of the participants was 13.1±1.8 years. The TFAT demonstrated high test-retest reliability with an ICC of 0.99 (95% CI:0.98-0.99) and Cronbach alpha of 0.99, as well as excellent content validity (I-CVI=1). Absolute reliability showed low SEM (0.25 sec) indicating good measurement precision, however the CV (28.7%) indicates relatively high variability; thus, absolute reliability should be interpreted cautiously despite excellent ICC. Validity criteria analysis demonstrated good discriminative capacity having an AUC of 0.74, high sensitivity (0.91), and moderate specificity (0.47). Bland-Altman analysis found little bias (0.082 s) with limited limits of agreement as well as no systematic error criteria. The high ICC indicates that TFAT provides consistent and reproducible agility measurements in school-going children supporting its use for monitoring performance changes.

Conclusion: The novel TFAT is a reliable, valid and practical tool for assessing agility in school-going children. Its simplicity, minimal equipment requirements and strong psychometric properties support its use in school based physical education and youth sports settings.

Keywords: Agility, Physical education, Physical fitness, Psychometric, Test-retest reliability

INTRODUCTION

One of the most important aspects of motor fitness is agility, which is necessary for any activity requiring quick changes in body position and its components is also necessary for acquiring and developing motor skills and sports tactics, particularly for movements that call for coordination [1]. Enhanced intramuscular coordination, better body control during rapid movements, and a lower chance of injury or reinjury are multiple benefits of enhanced agility [2-4]. A variety of tests have been designed to assess agility.

According to a more recent study in sports research, speed ability and agility motor quality are distinct and independent physical motor talents that require a high degree of muscular specificity development during growth [5]. A special focus should be placed on developing agility skills [6]. Coordination and movement control are the foundational elements of agility, and they must be considered independently from other influencing factors like balance, joint mobility, body power, flexibility, energy resource levels, strength, speed, and the biomechanical structure of movement [7].

Physical educators and coaches can evaluate motor competence, identify children who may need focused interventions, and analyse the efficacy of physical education curricula with the help of routine agility assessments in school settings. As a result, field-based agility tests that are simple, quick, and reliable are crucial for use in educational settings [8]. The improvement of agility skills, anticipation, and decision-making abilities should receive special focus [7].

Common agility tests include- Illinois Agility test, 5-0-5 Agility test [9] and shuttle run test [10]; however, many require larger space, longer distances or complex movement patterns. Furthermore, all the existing agility tests are not specifically validated in school-going children. Thus, the purpose of the study was to develop a novel TFAT and to evaluate its content validity, test-retest reliability and criterion validity in school-going children aged 10 to 16 years. The novelty exists in being a simple, space efficient and less time consuming and child friendly agility test suitable for routine physical assessment.

MATERIALS AND METHODS

A cross-sectional methodological study was conducted at MM International School Mullana, Ambala, Haryana, India between June 2025 to November 2025. Ethical approval was obtained from Institutional Ethics Committee (Approval no: SPC-PA-08). The study was conducted as per the COSMIN guidelines [11]. Written informed consent from parents and assent from children were obtained.

Inclusion criteria: Children with age 10 to 16 years, both boys and girls, able to understand the command and were willing to participate were included.

Exclusion criteria: Children with any systemic illness, musculoskeletal disorder, neurological disorder, psychological disorder, any injury of both upper and lower limb in past six months were excluded.

Sample size: A sample size estimation was guided by methodological recommendations; a minimum of 50 samples was required. Hence, as per availability, convenience sampling was used to assess test-retest reliability and criterion validity in 51 school-age children, aged 10 to 16 years.

Study Procedure

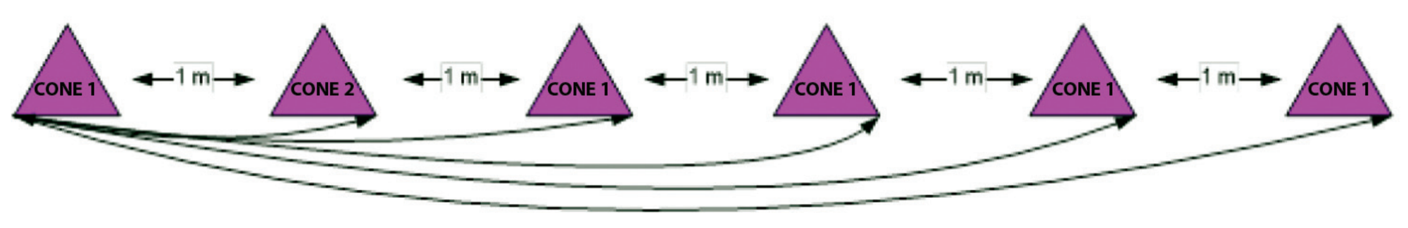
Development of TFAT: The TFAT was developed by the authors based on practical constraints observed in school-based physical assessment settings, including limited space, time constraints, and the need for a child-friendly agility test. The development was guided by the principles of change-of-direction agility testing used in shuttle-based agility tests [12,13]. For the width and length area, a five-meter test course setting using six cones was designed for the new agility test. In the newly developed test, six cones are placed at the distance of one metre, respectively. The total distance will be five meters. The child was asked to touch each cone one by one and to come back to the starting position. Total running distance is 30 metres and the child will come back to first cone after touching each cone. The time taken to complete the test is recorded. In this test, the speed and the change of direction is related to the agility [Table/Fig-1].

The 5-0-5 test was selected because it isolates change of direction ability with minimal influence of linear sprint speed making it a precise comparator for directional agility. It is also age appropriate, requires a similar space and equipment as TFAT ensuring practical and methodological consistency.

Diagnostic accuracy indices were calculated using a 5-0-5 cut-off value. This cut-off value was derived from the distribution of 5-0-5 agility test scores within the study sample, where it served as the reference for classifying agility performance. Receiver Operating Characteristic (ROC) curve analysis was conducted to evaluate the discriminative ability of TFAT. The selected cut-off was chosen to maximise sensitivity in identifying children with relatively lower agility performance, consistent with the intended role of TFAT as a screening tool for agility assessment in school-aged children.

Agility and fitness measurements TFAT: The test was conducted on a level, non slip surface. The distance between cone one and cone six was five meters due to the arrangement of six cones in a straight line that were precisely one meter apart. The child was asked to touch each cone one by one and to come back to the starting position i.e., cone-1. The duration in seconds taken by the child to complete the task was noted. The following sequence was given to children to finish:

Run from cone-1 to cone 6, Run from cone 6 to cone-1, Run from cone-1 to cone-5, Run from cone-5 to cone-1, Run from cone-1 to cone-4, Run from cone-4 to cone-1, Run from cone-1 to cone-3, Run from cone-3 to cone-1, Run from cone-1 to cone-2, Run from cone-2 to cone-1 as shown in [Table/Fig-1].



[Table/Fig-1]: Schematic diagram of test.

The child performed the test three times and the best time of the three test trials was noted. Using a regular digital stopwatch, timing started when the child initiated movement from cone-1 and ended when they returned to cone-1 following the final segment.

Content validity of the TFAT: The content validity of TFAT was assessed by six specialists, two of whom had more than 15 years of experience as sports physiotherapists and four with PhD. These experts were asked to respond to a question about the relevance of the agility test's content in evaluating the children's actual agility performance. Before the TFAT test's validity was evaluated, the experts were informed of the study's goal and implications and granted permission to take part. The experts were then shown the definition of agility, the to-and-fro test settings, and a short video featuring children performing the test. Based on these, the experts used the following 4-point Likert scale to evaluate the content validity [14] of the TFAT for the children. Scores are as follows: 1 is not relevant, 2 is slightly relevant, 3 is quite relevant, and 4 is highly relevant. Google Forms was used to gather the scores in an anonymous manner. Dichotomous variables "0" and "1" were created from scores of 1 or 2, which were irrelevant ratings, and 3 or 4, which were relevant ratings. The I-CVI, the primary outcome indicator, was calculated by dividing the number of experts who gave a relevant value of "1" by the total number of experts. The present agility test consists of one single item. The experts were asked to judge in terms of relevancy.

Test-retest reliability: To evaluate the test-retest reliability and criterion validity a total of 51 school-going children age 10 to 16 years were recruited using convenience sampling. A minimum of 50 samples is required to obtain stable reliability estimation as per Lynn, 1986 and Walter SD et al., 1998 [15,16]. For test-retest reliability of TFAT, data was recorded at two occasions with an interval of 48-hours.

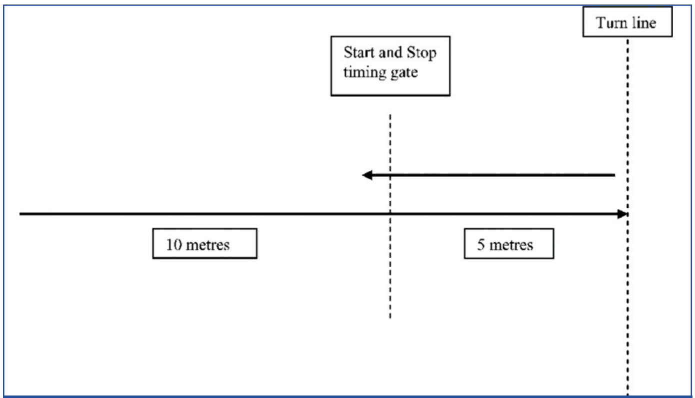
Criterion validity of TFAT using 5-0-5- test: Criterion validity of the TFAT was assessed using the 5-0-5 agility test as the reference [17].

5-0-5 Agility test

The test was conducted on the non slippery surface, administrator counted "three, two, one, go" while standing in line with the finish line. The child ran 15 meter to the turn line on "go," turned the track, and ran 5 metres through the finish line. The time was recorded from the stopwatch once the child accelerated across the finish line. The child performed the test three times, turning in each direction, and rested for two to three minutes in between. The best time of the three trials in each direction was recorded [Table/Fig-2] [17].

STATISTICAL ANALYSIS

Data are presented as means, Standard Deviation (SD), and 95% CI (95%CI). All statistical analyses were conducted with $p<0.05$, using IBM Statistical Package for Social Sciences (SPSS), version 26.0. For the purposes of relative reliability analysis and descriptive statistics, every demographic feature was represented. ICC, Cronbach's alpha, Bland-Altman plot, regression analysis, and SEM were calculated for absolute reliability. Minimal Detectable Change (MDC), Coefficient of Variance (CV%), and Smallest Worthwhile Change (SWC) [18] were used to assess the psychometric qualities of the TFAT. The SEM was calculated using the following formula



[Table/Fig-2]: The 5-0-5 test of agility [17].

SEM=SD×√(1-ICC) [16,19,20]. The SWC was calculated using 0.2 SD. For criterion validity ROC, AUC analysis, sensitivity, and specificity were calculated. COSMIN grading and criteria were used to critically evaluate each result.

RESULTS

Content validity: An ICVI of 1 was achieved. The Scale Content Validity Index (S-CVI/ Ave) was also 1, indicating excellent overall content validity with 100% expert agreement on the relevance and appropriateness of the test [Table/Fig-3].

S.NO	R1	R2	R3	R4	R5	R6	I-CVI
1.	1	1	1	1	1	1	1
S-CVI							1

[Table/Fig-3]: Content validity.

Participants characteristics: The study consisted of 25 boys and 26 girls. Demographic characteristics of the study participants including age, height, weight and Body Mass Index (BMI) is presented in [Table/Fig-4].

Variables	Total sample (Mean±SD)	Boys (n=25)	Girls (n=26)
Age	13.1±1.8	13.3±1.9	12.9±1.7
Height (cm)	153.4±11.6	156.2±9.8	150.2±8.9
Weight (kg)	41.0±8.15	43.0±8.7	39.1±7.6
BMI (kg/m²)	19.2±2.8	19.1±2.6	18.4±2.4

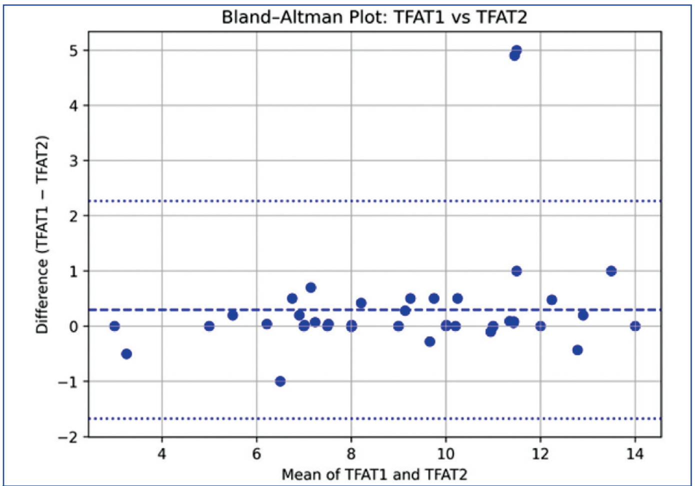
[Table/Fig-4]: Demographic characteristics of participants (N=51).

Reliability: The relative reliability of the to and fro test was assessed by using an ICC model 2,1 [21]. The test demonstrated excellent test-retest reliability with an ICC of 0.99 (95% CI). The SEM was 0.25 seconds indicating acceptable measurement precision, however, the CV=28.7% was relatively high, suggesting considerable relative variability in performance. Therefore, while relative reliability (ICC= 0.99) was excellent, absolute reliability should be interpreted carefully based on CV% as shown in [Table/Fig-5]. Bland-Altman analysis revealed a mean difference of 0.082 sec with narrow limits of agreement suggesting minimal measurement error and no systematic bias [Table/Fig-6].

With 95% limits of agreement ranging from -0.61 to 0.77, Bland-Altman analysis revealed a mean bias of 0.082 between TFAT1 and TFAT2 values. There was no discernible systematic bias because the CI in this study crosses zero (-0.017 to 0.181), it is likely due to random measurement variation rather than a consistent measurement error [Table/Fig-6,7]. This suggests that the TFAT produces stable and unbiased results when repeated, supporting the test–retest reliability and measurement agreement of the test [22].

Parameters	Value
Sample size (N)	51
Mean TFAT1	9.47
Mean TFAT2	9.4
Mean difference (Bias)	0.082
Standard Deviation (SD) differences	0.352
95% CI of Bias	-0.017 to 0.181
Lower LoA	-0.61
Upper LoA	0.77

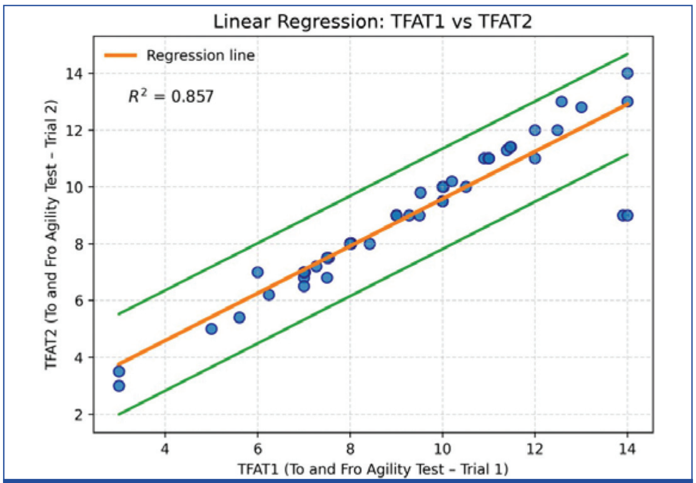
[Table/Fig-6]: Bland-Altman analysis.



[Table/Fig-7]: Bland-Altman Plot.

Regression analysis: The regression plot demonstrates a strong positive and practically meaningful relationship between TFAT 1 and TFAT 2. The high R2 (0.85) supports excellent test-retest reliability [Table/Fig-8].

The Bland-Altman analysis demonstrates suitable sample size, minimal mean bias near zero, low variability, and narrow boundaries of agreement, the basic Altman analysis shows satisfactory agreement [Table/Fig-9].



[Table/Fig-8]: Regression curve.

The reliability analysis shows excellent agreement with the regression slope close to 1, a near zero intercept and very high R2 value indicating strong linearity. Pearson correlation is extremely high and statistically significant meeting all COSMIN criteria for sufficient reliability [Table/Fig-10] [23].

Variables	Mean±SD	ICC (95%CI)	Cronbach alpha	SEM	CV%	SWC	MDC	Floor effect	Ceiling effect
TFAT1	9.47±2.89	0.99 (0.98-0.99)	0.99	0.25	28.7%	0.53	0.69	3.92% Absent	1.96% Absent
TFAT2	9.40±2.87								

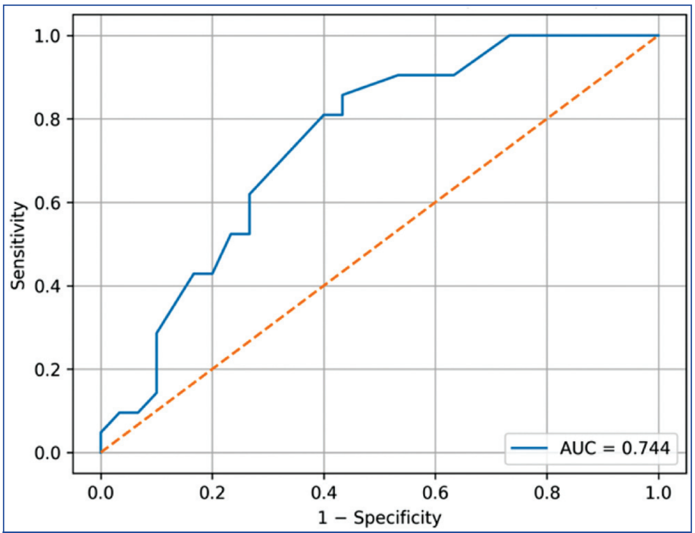
[Table/Fig-5]: Reliability indices of TFAT.

Parameters	Value	COSMIN criterion [11]	COSMIN grading
Sample size	51	Adequate sample size	Sufficient (+)
Mean bias	0.082	Bias close to zero	Sufficient (+)
SD of differences	0.352	Low relative error	Sufficient (+)
Lower LoA	-0.61	Narrow LoA	Sufficient (+)
Upper LoA	0.77	Narrow LoA	Sufficient (+)
95% CI	-0.017-0.181	CI includes zero	Sufficient (+)

[Table/Fig-9]: Bland-Altman agreement analysis with COSMIN grading.

Parameters	Value	COSMIN criterion	COSMIN grading
Regression equation	TFAT2=0.977× TFAT1+0.130	Slope≈1,intercept≈0	Sufficient (+)
Regression Slope	0.977	Strong linearity	Sufficient (+)
R2	0.857	R2>0.50	Sufficient (+)
Pearson Correlation	0.991	r≥0.70	Sufficient (+)
p-value	<0.001	Statistical significance	Sufficient (+)

[Table/Fig-10]: Reliability analysis (Regression) and correlation with COSMIN grading.



[Table/Fig-13]: Receiver Operating Characteristic (ROC) curve showing TFAT's capacity to distinguish between impaired and non impaired performance as determined by the 5-0-5 test (cut-off ≥ 8 seconds).

The results indicate that the median TFAT score was 9 (IQR 7.2 - 11) while the median time for the 5-0-5 agility test was 7.8 seconds (IQR 7.4-9). The Spearman correlation coefficient (rho=0 .667) demonstrates a moderate to strong positive relationship between TFAT and 5-0-5 agility test performance [Table/Fig-11].

Variables	Median (Quartiles)	Spearman rho	p-value
TFAT	9 (7.2-11)	0.667	<0.001
5-0-5 agility test	7.8 (7.4-9.0)		

[Table/Fig-11]: Correlation between TFAT and 5-0-5 agility test.

With an AUC of (74%) and high sensitivity (91%) but moderate specificity (47%) at an 8-second cut-off (derived by rounding off the median value of 5-0-5 test score of study sample), the TFAT displayed good overall discriminatory ability and supported its use as a screening tool for agility assessment rather than a definitive diagnostic test for agility performance [Table/Fig-12,13].

Metric	Estimate	95% CI
Sensitivity	91%	0.78-0.98
Specificity	47%	0.20-0.75
Area Under Curve (AUC)	74%	0.55-0.89

[Table/Fig-12]: Diagnostic accuracy of TFAT (5-0-5 test cut-off- 8s).

DISCUSSION

The key findings revealed excellent test-retest reliability (ICC=0.99; Cronbach's alpha=0.99), good content validity (I-CVI=1), and moderate criterion validity, with an AUC of 0.74. Additionally, the TFAT showed high sensitivity (0.91), moderate specificity (0.47), and minimal measurement error, as indicated by low SEM and negligible bias in Bland-Altman analysis. TFAT and 5-0-5 agility test performance demonstrated a moderate to strong positive relationship (rho=0.667, p<0.001).

Previous paediatric agility studies report ICC value ranging from 0.85 to 0.95 for field tests [24-26]. The present ICC (0.99) exceeds many previously reported values indicating excellent stability. Similarly, Morita N et al., (2022) reported high reliability for the N Challenge test supporting the feasibility of structured shuttle based paediatric agility assessments [20]. Compared with 5-0-5 test validity study, the AUC (0.74) in the present study indicates acceptable discriminative ability [27].

The current study used a thorough statistical framework that included Bland-Altman analysis, regression analysis, responsiveness metrics, reliability indices, and ICCs to assess the measurement features and agreement reliability between TFAT1 and TFAT2.

Bland-Altman analysis showed a relatively modest mean 0.082, showing little systematic error between the two measurements with narrow 95% margins of agreement of -0.61 to 0.77 Crucially, the bias's CI contained 0, indicating that there was no fixed bias. The restricted and clinically acceptable individual variability between TFAT 1 and TFAT2 is suggested by the narrow dispersion of discrepancies. Because Bland-Altman analysis evaluates absolute agreement rather than merely association, it is frequently advised for technique comparison research [22]. These conclusions were further reinforced by reliability analysis. According, to COSMIN criteria and generally accepted thresholds (ICC >0.90) for high quality measurements [23]. The ICC (ICC=0.991) demonstrated exceptional reliability. In comparison to between-subject variability, a high ICC indicates extremely minimal measurement error. Additionally, the internal consistency of measurements across methodologies was supported by Cronbach's alpha exceeding 0.99 [18]. When taken as a whole, these results verify that the observed agreement between TFAT1 and TFAT 2 is genuinely consistent rather than coincidental.

The SEM, which was low (0.25 units) and indicated high precision, was used to assess the absolute measurement precision. From a clinical perspective, the smallest change that can be considered a real change beyond measurement error is the minimal detectable change with 95% confidence (MDC95=0.69). An estimated 0.53 units was the smallest significant change. This trend is commonly seen in biological and biochemical tests and indicates conservative error estimation rather than inadequate responsiveness, even when MDC95 slightly exceeded the SWC [28-30]. The instrument's capacity to identify clinically significant changes in longitudinal evaluations is supported by the proximity of MDC and SWC as well as its exceptional reliability.

The absence of floor and ceiling effects and the fact that less than 15% of participants reached minimum or maximum levels further indicated responsiveness, confirming that the measurement sensitivity is adequate across the whole observed range. The responsiveness and interpretability of change scores depend on the lack of floor and ceiling effects, according to COSMIN guidelines [23].

Regression and correlation analysis showed that TFAT 1 and TFAT 2 had a strong linear connection. An excellent linear relationship was further demonstrated by Pearson's correlation analysis (r=0.991, p<0.001). The convergence of regression correlation, Bland-Altman, and reliability analysis offers strong evidence that the two measurements act consistently over the observed range, even though high correlation by itself does not imply agreement [31].

The use of several complementary statistical techniques, adherence to COSMIN guidelines, and evaluation of both relative and absolute reliability are among the study's methodological advantages. A Spearman correlation analysis was conducted to examine the relationship between TFAT and 5-0-5 agility test. This finding supports the criterion validity of TFAT suggesting that children who performed better on 5-0-5 test also showed better performance on TFAT. The strength of the correlation indicates that TFAT is comparable to an established agility test while offering advantages and simplicity and feasibility for school settings. The low specificity 47% limits the test effectiveness for accurately classifying non-impaired individuals. Although TFAT demonstrated high sensitivity making it useful for identifying children who may require further evaluation, it should not be used as a stand alone diagnostic tool instead it is more appropriately applied as an initial screening measure followed by more specific assessments to confirm agility deficit.

Limitation(s)

The study has certain drawbacks that should be addressed. Firstly, while the sample size complied with fundamental COSMIN guidelines, it was still quite small overall, and convenience sampling method was used, which may make it more difficult to generalise the findings to a larger group of children. Secondly, only a single tool that is 5-0-5 was used for the criterion validity. Future studies might use larger samples from more diverse groups of children with motor difficulties. The tool would be considerably more useful for educators, coaches, and clinicians in real-world settings if normative values would be finally developed for various age groups and genders.

CONCLUSION(S)

The innovative TFAT is a valid and consistent method for evaluating school-age children's agility. It is appropriate for its utility in school physical education programs and youth sports environments due to its ease of use and practicality. TFAT exhibit good responsiveness and outstanding agreement reliability. These measurements can be used interchangeably for cross-sectional and longitudinal analysis due to their low measurement error, strong linear relationship, and lack of floor or ceiling effects. These results provide evidence to the assessment approach's validity and clinical utility in both practical and research contexts.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Feb 11, 2026
- Manual Googling: Apr 13, 2026
- iThenticate Software: Apr 15, 2026 (1%)

ETYMOLOGY: Author Origin

EMENDATIONS: 8

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Feb 03, 2026**
Date of Peer Review: **Feb 27, 2026**
Date of Acceptance: **Apr 17, 2026**
Date of Publishing: **Jun 01, 2026**