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Adapting The Bruininks-Oseretsky Test of Motor Proficiency (BOT-2) for Young Athletes

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Research Article

Abstract:
The original Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) is heavily used to detect motor impairments. It has shown limitations when applied to athletic population due to ceiling effects and low score variability among skilled youth. This pilot study aimed to evaluate an adapted version of BOT-2 tailored for young athletes aged 13–17 by incorporating dynamic and time-based components to enhance discrimination and engagement. The adapted BOT-2 included tasks spanning two motor domains: Drawing Lines and Folding Paper (Fine Motor Precision), and Transferring Pennies (Manual Dexterity), modified with time constraints. Descriptive statistics, reliability analysis (Cronbach's Alpha), ceiling effect inspection, and correlation matrix analysis were conducted to assess the performance variation and internal consistency. The obtained results revealed that specific retained tasks, particularly Drawing Lines and Folding Paper, exhibited strong ceiling effects. In contrast, the time-adapted tasks such as Dribbling and One-Legged Hop showed greater score variability and stronger differentiation. Principal Component Analysis further supported the multifactorial nature of motor proficiency, identifying four distinct components that accounts for 82.23% of total variance. These component groupings reflected agility, balance-related control, and fine motor integration. These findings highlight the potential of sport-specific BOT-2 adaptations and offer insights into optimizing motor proficiency assessments for developmental athletic populations, meriting further investigation.

Keywords: BOT-2; Motor proficiency; Measurement; Young athlete

1. INTRODUCTION

Among the available tools for measuring motor proficiency in children and adolescents between 4 and 21 years old, the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2), remains one of the most commonly recognized and frequently used (1). Professionals in clinical, educational and research settings often rely on the BOT-2 as a thorough measure. They use it both for detecting motor difficulties and assessing fine and gross motor proficiency in various areas. The BOT-2 consists of eight subtests, assessing fine motor precision, integration, manual dexterity, bilateral coordination, balance, running speed and agility, upper limb coordination and strength. Its broad scope has led many to consider the BOT-2 the standard method for examining motor proficiency, particularly in developmental and clinical environments. While the BOT-2 remains a gold-standard tool for general populations, adapting it for elite and athletic groups is essential to capture the complexity of their motor proficiency profiles accurately.

The motor proficiency of young athletes aged 13 to 17 often differs from that of their peers in the general population. Their training and experience in sport commonly help them develop refined motor abilities at a key period in their growth (2). This pattern has led to growing interest in updating and customizing the BOT-2 to better match the needs of talented youth athletes. However, specific subtests often show ceiling effects and limited variation, as many participants perform at the highest possible level making it difficult to distinguish athletes with differing skill levels (3). Consequently, the BOT-2 may not always capture the full extent of advanced motor proficiency in high-performing youth athletes.

This challenge becomes more evident when using the BOT-2 Short Form (SF), which is often chosen for its shorter administration time than the Complete Form (CF). Despite its convenience, the SF may lack the sensitivity to detect high-level motor skill differences. Comparisons between SF and CF have shown no significant or meaningful distinctions, raising concerns about its effectiveness in athletic contexts (4). These outcomes highlight the need to enhance the BOT-2's ability to recognize higher motor skill levels, particularly among athletes. Therefore, integrating performance-based assessments with self-report questionnaires appears beneficial, as Brown has suggested (5).

Brown's study indicated that relying solely on instruments such as the BOT-2 may not reflect the complete range of motor competence in children or athletes, especially in sports contexts. When evaluators use subjective measures like the

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Physical Self-Description Questionnaire (PSDQ) and objective motor performance scores, they can develop a broader understanding. This approach provides insight into how young athletes perceive their abilities, adding depth to the BOT-2 results. Moreover, subjective tools help account for psychological aspects, which are vital for athletes who often portray greater self-awareness and confidence in their performance. Additional limitations of the BOT-2 SF include a sensitivity rate of 84% and a low specificity of only 42.9%, making it challenging to differentiate average from high-performing individuals (4). The SF also explained just 57% of the variance found in the CF, suggesting that the two versions may measure somewhat different constructs. These findings underscore the need to revisit and adjust the BOT-2 format for athletic populations.

In standard BOT-2, selecting appropriate task types presents further limitations. While fine motor precision and manual dexterity can help spot developmental delays, they do not reflect the specific motor proficiency required for athletic success (6). For well-trained athletes, simple movement tasks may not match their level of capability. Dynamic tasks such as ball dribbling, one-leg hopping, and rapid coordination activities offer a more relevant assessment (7). These tasks better represent the agility, speed, balance, and time-sensitive coordination demanded in sports. Incorporating them into the BOT-2 can enhance its discriminatory power. Modifications should also prioritize strong reproducibility, consistent results, and construct validity to ensure the test remains reliable for identifying talent and tracking athlete development (7).

When internal consistency is lacking, particularly among elite athletes whose results may vary across tasks, the test outcomes may fail to reflect actual abilities. Evidence suggests that challenging motor coordination tasks, such as ball dribbling and hopping, produce greater variation and better distinguish performance levels than simpler tasks (2). Timed activities such as repeated hopping, jumping, and coin transfer can increase difficulty and test coordination, endurance, and response speed more effectively. However, most current tools, including the BOT-2, focus on developmental delays and often overlook the refined motor skills required in sports settings (6).

As the demand for validated athletic assessment tools grows, modifying established measures like the BOT-2 may address this shortfall. Motor proficiency, comprising fine and gross motor abilities, is central to athletic development and success. Although the BOT-2 was designed to identify motor difficulties, it may not sufficiently measure the advanced abilities of youth athletes. Issues such as ceiling effects, narrow scoring ranges, and long testing durations limit its effectiveness in competitive contexts. To overcome these barriers, this study aims to adapt the BOT-2 by incorporating dynamic tasks, increasing task difficulty, and shortening test duration. These modifications intend to capture motor proficiency in athletic youth better, offering more accurate tools for identifying talent, customizing training, and tracking progress over time.

2. METHODOLOGY

This study employed a modified version of the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) to evaluate the motor skills of young athletes aged 13-17. The selection of this instrument was based on its previous adaptations, especially those targeting specific populations such as children with disabilities (8). The procedures in this study on human participants were approved by Universiti Teknologi MARA's ethical committee with reference number, REC/02/2024 (PG/MR/86).

2.1 Instrumentation Adaptation

To more accurately reflect the varied and demanding nature of athletic settings, we introduced timed, dynamic elements to three subtests selected from the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2). The researchers had several aims in making these adjustments. They wanted to improve the test's sensitivity to minor differences in motor proficiency, address ceiling effects and increase its relevance for young people who are both typically developing and active in sports. Each subtest was adapted to include assessments based on speed and dynamic movement. In the revised One-Leg Hopping subtest, timing was incorporated.

Participants attempted to perform as many continuous, successful hops as possible for one minute. This modification allowed the subtest to more accurately measure key qualities of the lower body, such as neuromuscular coordination, movement control, quickness, and muscular stamina. By increasing mental and physical demands, this version made distinguishing between individuals with advanced and average motor abilities easier. Previous studies in sports science have highlighted the importance of single-leg strength and movement control, particularly in sports requiring rapid changes of direction such as basketball, soccer, and sprinting (9). Using a timed, performance-focused approach now more closely matches the realities of sports, where repeated and forceful lower-body movements require constant balance and control. This setup also enables researchers to monitor how ongoing exertion may gradually affect performance, providing deeper insights into the endurance aspects of motor skill proficiency.

Jumping in Place: Examiners now use a timed approach to measure performance in the updated version of the Jumping in Place subtest. They record how many correct jumps each person completes during a fixed period. Adding this time limit lets those conducting the test observe anaerobic endurance and an athlete's sense of timing, balance and ability to coordinate movements while tired. When fatigue builds, the skill to keep producing strong jumps becomes especially relevant in sports that require frequent bursts of power, such as volleyball, gymnastics, and basketball (10). With this adjustment, the subtest moves from simply measuring jumping skill to providing a more demanding test highlighting a wider range of abilities, helping professionals spot any weaknesses in stamina or performance consistency.

Transferring Pennies: The modified Transferring Pennies subtest, which has long measured small muscle control and hand skill, also includes a time restriction. Participants try to move as many pennies as possible within this set period. This change makes the task more challenging, forcing a balance between speed and accuracy. It is a common issue in activities where athletes must handle objects quickly, such as passing in netball or handball. Previous studies have indicated that specific BOT-2 subtests may not effectively differentiate among typically developing children. Four of the eight items for the four subtests had very low associations with their subtest total score, suggesting potential ceiling effects (11). By limiting the time available, the task tests precision and coordination and how quickly one can think and react under pressure. This mirrors the fast-paced nature of many sports, where athletes must perform exact skills even when time is short. Prior studies suggest that combining speed and accuracy in these tests can better predict athletic success in particular sports than using either measure by itself (12).

Adaptations to the BOT-2 aim to reduce ceiling effects observed in specific populations, enhancing its ability to distinguish individuals with advanced motor proficiency (13). By raising both cognitive and physical requirements in each task, the updated format poses greater challenges for test-takers. This change allows the assessment to better distinguish between participants. In training settings, coaches need to pinpoint particular strengths and weaknesses to guide skill development, so this improvement holds particular value. Including time-based elements also helps the test better reflect real-life conditions. Sports often require athletes to perform while tired and within time constraints. Practical concerns about using the BOT-2 in school field settings also shaped the adaptations. Among youth with typical development and among athletes, some researchers have found that specific BOT-2 items repeat skills and show slight variation in results (14).

2.2 Participants

This study involved ten secondary school soccer athletes aged 13–15 actively engaged in structured sports training programs. Before participation, informed consent was obtained from their school administrators and legal guardians. While the small sample size (n = 10) limits the generalizability of the findings, it was considered appropriate for piloting the adapted BOT-2 protocol and identifying areas needing refinement. As a pilot, this study is intended to inform and guide future large-scale research on motor proficiency assessments tailored for young athletes.

2.3 Instrumentation for Experiment

This assessment was modified after considering the feedback of the adapted version by two experts. In this study, fine motor control refers to tasks involving small, precise hand movements and fine object manipulation, such as Drawing Lines, Folding Paper, and Transferring Pennies. In contrast, manual coordination encompasses broader upper-limb movements that require hand-eye coordination in more dynamic contexts, like ball dribbling. While both domains rely on upper limb use, fine motor control emphasizes precision and delicacy, whereas manual coordination involves spatial awareness and larger-scale motor planning.

The adapted BOT-2 included tasks across four main domains: Fine Motor Precision: Drawing Lines, Folding Paper; Manual Dexterity: Transferring Pennies (with a time-based component); Upper Limb Coordination: Dribbling a Ball.; Bilateral Coordination: Standing on a Balance Beam.; Strength and Agility: Push-Ups, Sit-Ups, One-Legged Hop (including timed repetitions for greater variability and discriminatory power). Several tasks were modified to reflect the athletic movement's dynamic and performance-based nature. Specific original BOT-2 items were intentionally retained, such as Drawing Lines, Folding Paper (fine motor precision), Copying a Square and Copying a Circle (fine motor integration), as well as Standing on a Balance Beam and Walking Forward on a Line (balance). These tasks were preserved for two reasons: (1) maintain alignment with the original BOT-2 framework, and (2) evaluate whether standard items could still differentiate performance among trained adolescent athletes.

Despite the participants' athletic background, assessing whether these unmodified tasks would yield meaningful variability was methodologically important. Their inclusion enabled direct comparisons between adapted and retained tasks, allowing for assessment of the impact of dynamic modifications. For instance, Standing on a Balance Beam, though unchanged, remained a useful measure of static balance and provided a valuable benchmark when compared with more dynamic balance-related tasks. Consistently high performance on retained tasks validated the study's central premise: the original BOT-2 may not adequately reflect the motor proficiency of athletic youth. This justified the requirement for adaptation and supported the argument that dynamic tasks offer improved scoring sensitivity and a broader performance range. While assessments were not blinded, all raters followed standardized scoring rubrics, and examiner training was conducted to minimize the risk of bias.

2.4 Procedure

The researchers tested inside a school hall, keeping the environment the same for everyone to ensure fairness across participants. For each activity, observers assigned scores on a 1-10 scale and tracked timing details. Each participant's performance was recorded as the total time taken (in seconds) to complete the task. Since BOT-2 scoring traditionally uses a 1–10 scale, we developed a data-driven approach to transform raw times into norm-based scores within this framework. A pilot dataset of 10 participants was employed to establish initial norms. First, raw completion times were assessed using descriptive statistics to understand the performance distribution. Each value was converted into a z-score, where lower times (indicating faster performance) received higher z-values. These z-scores were subsequently transformed into percentile ranks, comparing performance across participants on a standardized scale. To align this with the BOT-2's 10-point scoring system, percentile ranks were grouped into decile bands, each of which corresponded to a score from 1 to 10. The fastest performance (e.g., in the lowest 10th percentile for time) received a score of 10, while the slowest (e.g., above the 90th percentile) received a 1. This reversed direction ensures that lower completion times yield higher scores, consistent with the test's performance-based nature. Tasks including the One-Legged Hop, Jumping in Place and Transferring Pennies included timed components. By making these changes, the team hoped to enhance the reliability and validity of how they measured motor proficiency. All evaluations occurred in an indoor sports facility, where the same procedures were applied. Prior to starting, participants completed a dynamic warm-up, which helped lower the chance of injury and supported similar physical readiness. Each task came with clear instructions and was demonstrated first. Participants also practiced each activity before the primary test to ensure they understood what to do.

2.5 Data Analysis

The researchers analyzed the data using IBM SPSS. Descriptive statistics were used to assess how scores varied, reporting the average and standard deviation values. Internal consistency was obtained by running a reliability analysis with Cronbach's Alpha. By observing at how scores spread out, the identification of any Ceiling Effect was conducted, which could show clusters at the high end of the scale. A Correlation Matrix was created as the final step to examine how the tasks related to each other.

3. RESULTS

3.1 Descriptive Analysis

Descriptive statistics were calculated for all 14 tasks to assess variability in performance across the sample (n = 10). According to Table 1, retained fine motor tasks such as Drawing Lines (M = 9.50, SD = 0.527) and Folding Paper (M = 9.30, SD = 0.675) yielded high mean scores with minimal score range (9–10 and 8–10, respectively), suggesting limited differentiation between participants and potential ceiling effects. Similarly, Copying a Square (M = 8.70, SD = 0.483) and Jumping in Place (M = 8.50, SD = 0.527) demonstrated minimal spread.

In contrast, tasks adapted to include time pressure or physical demand, such as Push-Ups (M = 7.00, SD = 0.816), Sit-Ups (M = 6.80, SD = 0.789), and One-Legged Hop (M = 7.90, SD = 0.738), demonstrated broader score distributions and higher standard deviations. These tasks showed a wider performance spread (score range: 6–8 or 7–9), indicating greater sensitivity in capturing participant performance differences. Cronbach's Alpha was computed to evaluate the internal consistency of the full task battery. The overall reliability coefficient for all 14 tasks was α = 0.29, indicating poor internal consistency and suggesting that the tasks may not cohesively measure a single latent construct.

Table 1. Results of Task Variability and Cronbach's Alpha (n=10).

Task	Min.	Max	Mean	SD	Cronbach's Alpha, α
Drawing Lines	9	10	9.50	0.527	0.334
Folding Paper	8	10	9.30	0.675	0.433
Copying a Square	8	9	8.70	0.483	0.312
Copying a Star	7	9	8.50	0.707	0.554
Transferring Pennies	6	8	6.90	0.568	0.461
Drop and Catch a Ball	6	8	7.10	0.568	0.579
Dribbling Ball	7	9	8.30	0.675	0.507
Jumping in Place	8	9	8.50	0.527	0.321
Tapping Feet and Fingers	7	9	8.10	0.738	0.288
Walking Forward on a Line	7	9	8.30	0.675	0.257
Standing on a Balance Beam	7	9	8.20	0.789	0.406
One-legged Hop	7	9	7.90	0.738	0.434
Push-ups	6	8	7.00	0.816	0.345
Sit-ups	6	8	6.80	0.789	0.402

3.2 Ceiling Effects

Ceiling effects were analyzed using histograms for each task. Tasks such as Drawing Lines (Figure 1), Folding Paper (Figure 2) and Copying a Square (Figure 3) demonstrated visible clustering of scores at the upper end of the scale, confirming ceiling effects in these retained fine motor items. Histograms were constructed individually using SPSS for each task by navigating to Graphs > Legacy Dialogs > Histogram. Variables were selected separately, and "Display normal curve" was enabled to compare distributions visually. The "Panel by rows/columns" options were kept empty to ensure a single-task display per chart. Tasks were selected for ceiling effect inspection based on the following criteria: High mean scores (≥ 8.5 out of 10), Low standard deviations (≤ 0.6), and narrow score ranges, especially those limited to 8–10. This was applied to Drawing Lines (M = 9.50, SD = 0.527), Folding Paper (M = 9.30, SD = 0.675), and Copying a Square (M = 8.70, SD = 0.483). The histograms revealed visible clustering at the high end of the scale, especially for Drawing Lines and Folding Paper, where over half of the participants scored a 9 or 10. This confirmed the presence of strong ceiling effects in these tasks. Copying a Square demonstrated moderate clustering near the top, but retained slightly more variability, suggesting partial sensitivity. These ceiling trends support concerns that static or fine-motor tasks in the original BOT-2 may not provide sufficient challenge or differentiation in athletic youth samples, where baseline proficiency tends to be elevated. The findings justify the inclusion of more challenging tasks in adapted motor assessments.

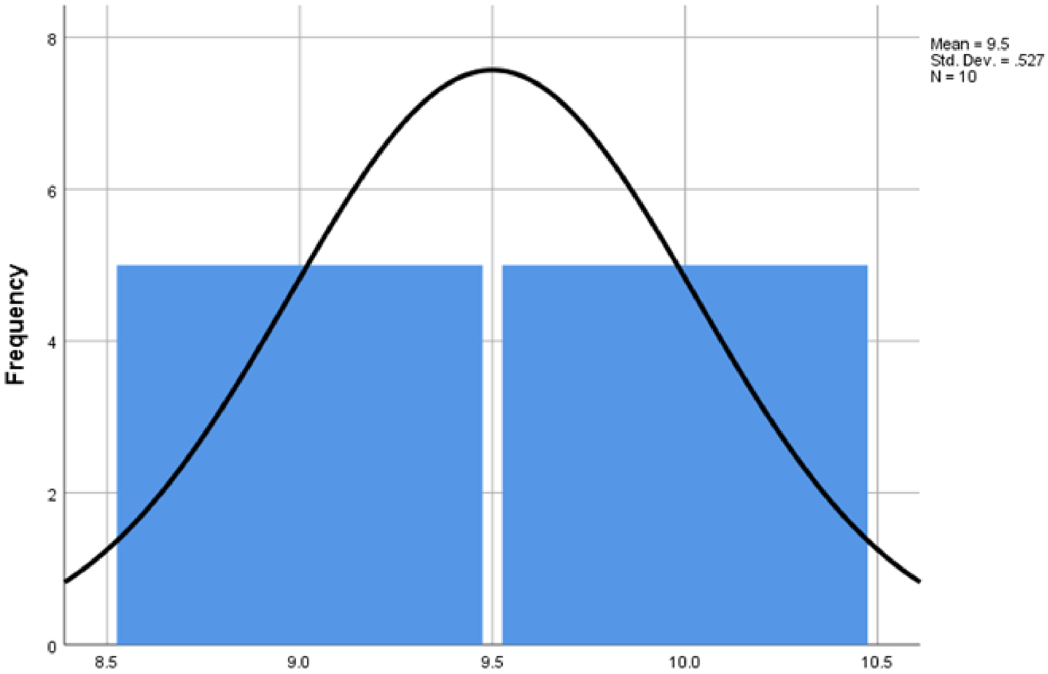

Figure 1. Ceiling effect of Drawing Line task.

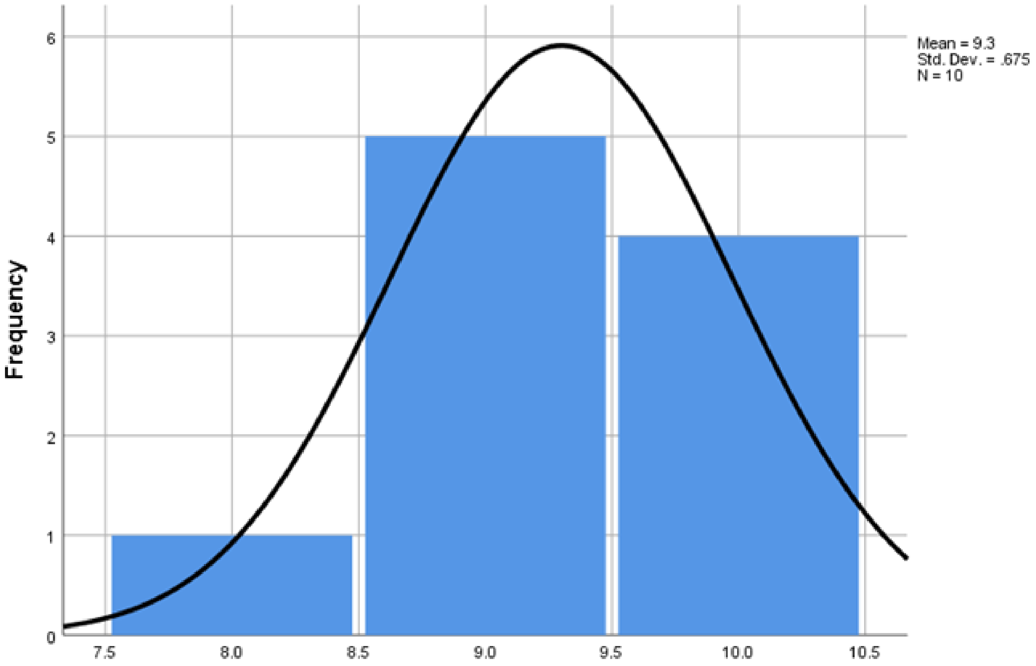

Figure 2. Ceiling effect of Folding Paper task.

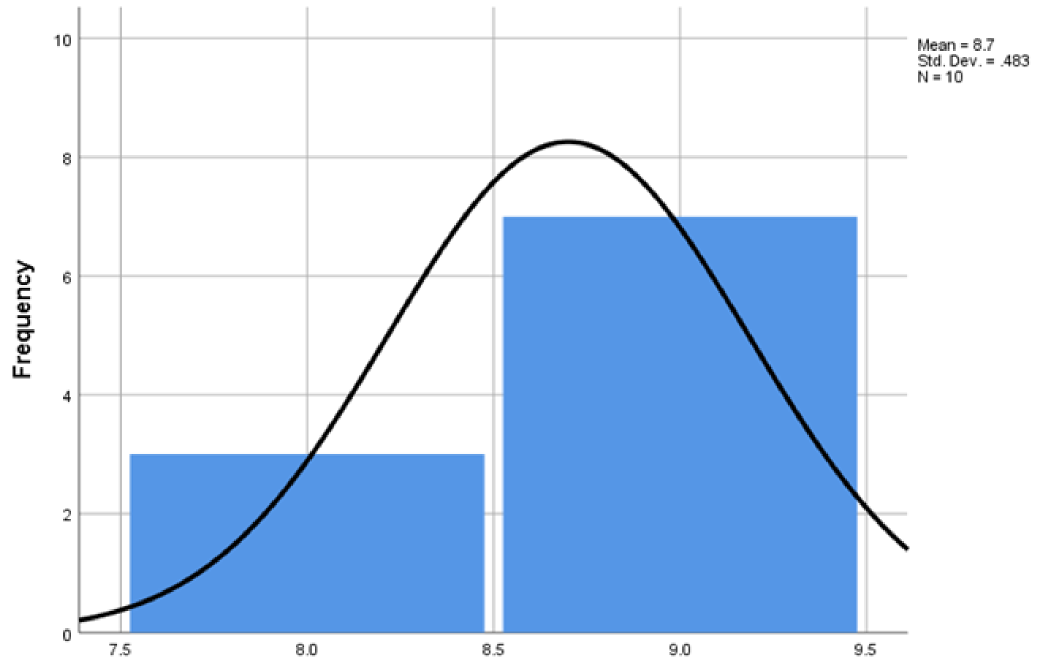

Figure 3. Ceiling effect of Copying Square task.

3.3 Task Correlation Matrix

A heatmap was developed to visualize the Pearson correlation coefficients among the 14 BOT-2 tasks (Figure 4). Strong correlations were observed between fine motor tasks (e.g., Drawing Lines and Copying Square, r = 0.66). In contrast, dynamic tasks such as Push-Ups and One-Legged Hop showed negative correlations (r = –0.74), suggesting distinct motor proficiency demands. This pattern supports the multidimensional nature of motor proficiency within athletic populations.

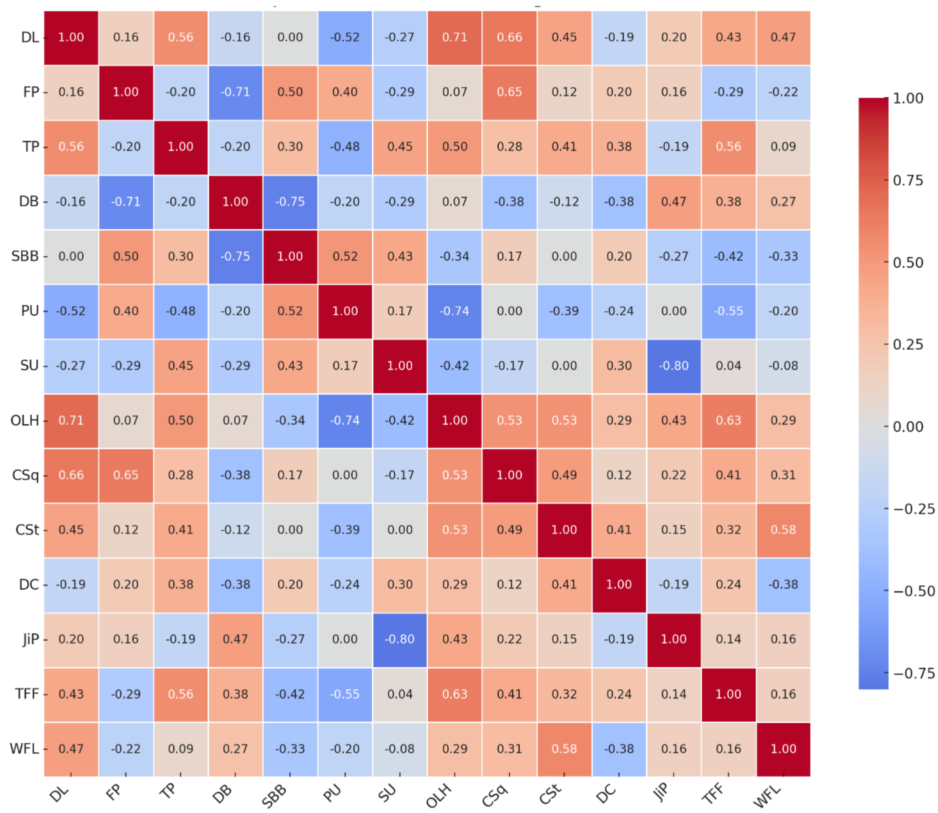

Figure 4. Heatmap of Pearson correlation among BOT-2 tasks.
Label: DL = Drawing Line; FP = Folding Paper; DB = Dribbling Ball; SBB = Standing on Balance Beam; PU = Push-Ups; SU = Sit-Ups; OLH = One-legged Hop; CSq = Copying Square; CSt = Copying Star; DC = Drop and Catch a Ball; JiP = Jumping in Place; TFF = Tapping Feet and Fingers; WFL = Walking Forward on a Line.

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The color gradient reflects the strength and direction of relationships among tasks. Darker red tones reflect stronger positive correlations (closer to +1.00), suggesting that the tasks may measure similar motor constructs. In contrast, deeper blue shades represent negative correlations (closer to -1.00), indicating that the tasks may assess differing or opposing motor abilities. Pale or neutral-colored cells show weak or no correlation, showing minimal overlap between task demands. This presentation helps to visually differentiate clusters of related motor skills and highlights areas of separation within the battery.

3.4 Composite Score Analysis

Table 2 presents descriptive statistics for composite motor domains. Scores are based on a 1–10 percentile scale, subtests averaged within each domain. Composite scores were computed by averaging the relevant subtests within each category to better understand domain-level motor performance. Table 2 presents the descriptive statistics for all six motor domains. Fine Motor Precision (FMP) showed the highest overall performance (M = 9.40, SD = 0.459), with scores tightly clustered between 9 and 10, suggesting a potential ceiling effect. Fine motor integration (FMI) also displayed a high mean performance (M = 8.60, SD = 0.516), although it spread slightly wider. Both domains indicate well-developed fine motor abilities in the sample, consistent with previous concerns regarding ceiling effects in BOT-2 fine motor tasks. In contrast, greater variability was observed in Manual Dexterity (M = 6.90, SD = 0.568), indicating more sensitivity to performance differences. Upper Limb Coordination (ULC) (M = 7.70, SD = 0.35) showed relatively high scores with limited spread. In contrast, Bilateral Coordination (BC) (M = 8.30, SD = 0.483) and Balance (Bal) (M = 8.25, SD = 0.425) demonstrated moderate consistency in participants' gross motor control. These domain-level scores highlight that adapted tasks within manual and strength-related domains offered greater variability, suggesting improved differentiation among athletic youth compared to the more static or fine motor domains. This supports the argument that future adaptations should prioritize dynamic, sport-relevant tasks that more accurately capture individual skill differences.

Table 2. Results of Composite score analysis (n=10).

Domain	Minimum	Maximum	Mean	SD
Fine Motor Precision	9.0	10.0	9.40	0.459
Fine Motor Integration	7.5	9.0	8.60	0.516
Manual Dexterity	6.0	8.0	6.90	0.568
Upper Limb Coordination	7.0	8.0	7.70	0.350
Bilateral Coordination	7.5	9.0	8.30	0.483
Fine Motor Precision	9.0	10.0	9.40	0.459
Balance	7.5	9.0	8.30	0.425

3.5 Composite Correlation Heatmap

Figure 5 illustrates the heatmap of Pearson's correlation coefficients among the six computed motor domains. A warmer color (red) indicates a stronger positive relationship, while cooler colors (blue) reflect negative correlations.

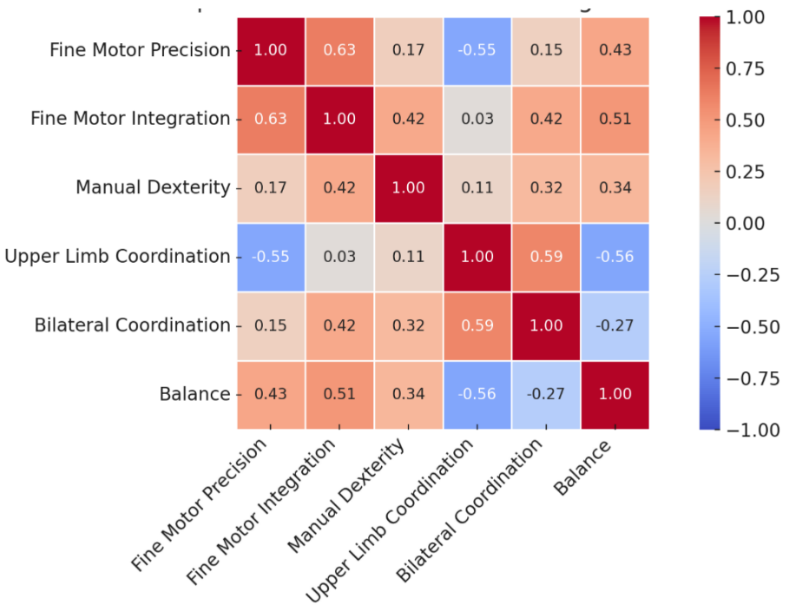

Figure 5. Heatmap of Pearson correlation coefficients between domains.

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Fine Motor Precision (FMP) showed a significant positive correlation with Fine Motor Integration (FMI; r = .63), suggesting aligned performance across fine motor subtests. In contrast, Upper Limb Coordination was negatively correlated with FMP (r = –.55) and Balance (r = –.56), reflecting divergent task demands. The variation in correlations across domains supports the multidimensional nature of motor proficiency assessed in this study.

3.6 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was carried out in Table 3 using Varimax rotation to assess the underlying structure of the adapted BOT-2 tasks. The analysis revealed four components with eigenvalues greater than 1, in line with the Kaiser criterion. These four components explained a total of 82.23% of the variance. Post rotation, the first component, accounted for 29.82%, the second 21.67%, the third 18.59%, and the fourth 12.14% of the variance, respectively. This distribution indicates a multifactorial structure of motor skill proficiency, with each component contributing meaningfully to the construction. The scree plot (Figure 6) supported the retention of four components, showing a clear inflection point (“elbow”) after the fourth component. This suggests that the first four components capture the most meaningful variance in the dataset, while subsequent components contribute only marginally. This reinforces the component structure identified in the Principal Component Analysis, confirming that four underlying motor dimensions, potentially corresponding to agility, balance-related control, fine motor coordination, and strength, offer a meaningful representation of performance variation among young athletes.

Table 3. Total variance explained by four principal components extracted using Varimax rotation.

Component	Eigenvalue	% of Variance	Cumulative %
1	4.17	29.82	29.82
2	3.03	21.67	51.49
3	2.60	18.59	70.08
4	1.70	12.14	82.23

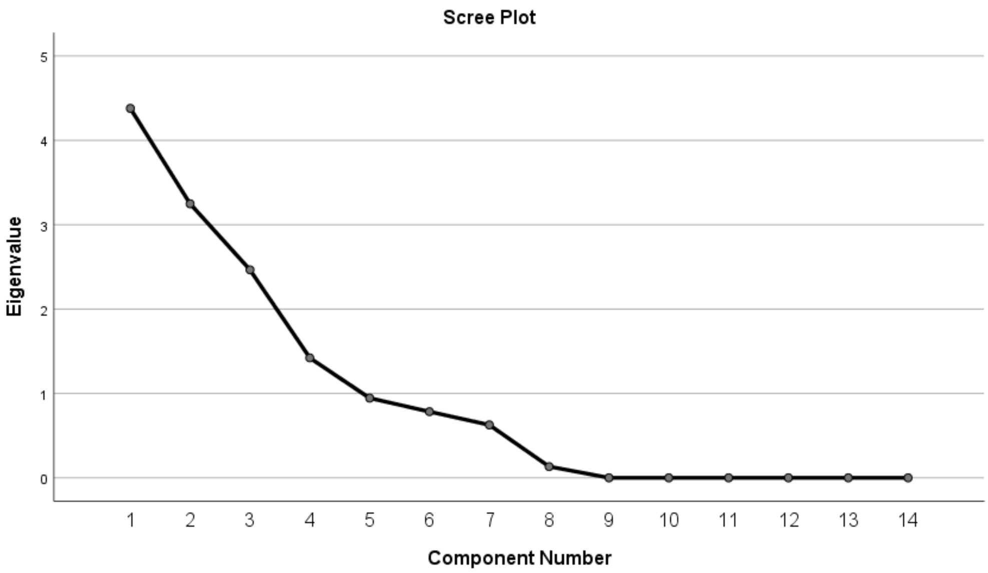

Figure 6. Scree Plot of four principal components.

4. DISCUSSION

This study provides preliminary evidence on the effectiveness of adapting the BOT-2 to assess sport-specific motor proficiency in young athletes aged 13–17. Descriptive statistics revealed that tasks such as Drawing Lines (M = 9.50, SD = 0.527) and Folding Paper (M = 9.30, SD = 0.675) showed limited variation and pronounced ceiling effects, making them noteworthy. Almost all participants scored highly (≥ 9), restricting the test’s ability to distinguish among competent young athletes. Ceiling effects occur when most individuals reach top scores, a recognized challenge in standardized testing (3). Prior research indicates that ceiling effects reduce a test’s ability to monitor improvement and mask subtle differences in motor proficiency among top performers (15). These results suggest that tasks exhibiting minimal variation are unsuitable for evaluating advanced motor proficiency in sports settings, where distinguishing elite-level capabilities is essential.

In contrast, tasks such as Dribbling a Ball (M = 8.30, SD = 0.675), One-Legged Hop (M = 7.90, SD = 0.738), and Transferring Pennies (M = 6.90, SD = 0.568) displayed greater score variation, offering better sensitivity for detecting performance differences. By integrating time pressure and physical exertion, these dynamic tasks improved discrimination between skill levels, especially relevant in athletic groups. Similarly, there is one study that emphasizes the value of including complex, time-sensitive tasks in athlete assessments (2). These results underscore that agility, endurance, and coordination-based tasks reflect sport-relevant demands better than static precision tasks. Reactive agility tests, which combine cognitive and motor components, have been shown to more effectively discriminate between athletes of varying performance levels than traditional pre-planned change-of-direction tests (16).

The composite score analysis supports this distinction. Fine Motor Precision (FMP) (M = 9.40, SD = 0.459) and Fine Motor Integration (FMI) (M = 8.60, SD = 0.516) demonstrated the highest performance and tight score clusters, confirming ceiling trends in fine motor domains. In contrast, Manual Dexterity (MD) (M = 6.90, SD = 0.567) and Balance (M = 8.25, SD = 0.424) demonstrated broader distribution, indicating greater variability. Upper Limb Coordination (ULC) (M = 7.70, SD = 0.349) and Bilateral Coordination (BC) (M = 8.30, SD = 0.48) reflected moderate variability and stronger alignment with dynamic performance demands. Studies indicate that participation in team sports like soccer and basketball enhance gross motor proficiency more significantly than fine motor proficiency, highlighting the emphasis on whole-body coordination in these activities (17). Conversely, sports require precise, isolated movements, such as archery, rely heavily on manual dexterity, with elite performers showing more refined muscle coordination patterns than novices (18).

The composite correlation heatmap indicated a significant relationship between FMP and FMI ($r = .63$, $p < .05$), suggesting consistent performance across fine motor domains. This link emphasizes the close relationship between fine motor control and overall body movement efficiency, which plays a crucial role in sports requiring precision and smooth coordination, such as object control (throwing or catching a ball) or fundamental movements like jumping (running jumping skipping) (19). However, Upper Limb Coordination (ULC) was negatively correlated with both Fine Motor Precision (FMP) ($r = -.55$) and Balance ($r = -.56$), indicating divergent motor demands and supporting a multidimensional structure in motor proficiency.

The Principal Component Analysis (PCA) clarifies this structure. Four components were extracted, collectively explaining 82.23% of the total variance. The first component explained 29.82%, the second 21.67%, the third 18.59%, and the fourth 12.14%. This suggests that motor proficiency is multifactorial, with key groupings likely corresponding to fine motor control, coordination, strength and agility, and balance. The scree plot confirmed the four-component solution. The interplay between fine motor control and overall body coordination is critical for athletic performance, as these motor domains are interconnected and collectively contribute to skill execution (20).

The internal consistency of the full task battery was low (Cronbach's $\alpha = 0.29$), indicating that not all tasks cohesively measured the same construct. Tasks like Push-Ups and Dribbling a Ball had weak internal consistency, suggesting functional independence from fine motor items. Conversely, tasks such as Copying a Square and Copying a Star contributed positively to internal consistency, reinforcing that fine motor tasks form a distinct cluster. This finding supports the concept that dynamic or physically demanding tasks may be functionally independent from fine motor tasks. Studies have regularly stressed the importance of balancing test variety with an appropriate difficulty range to assess motor proficiency accurately (21).

Overall, the findings support modifying the BOT-2 to more accurately assess motor proficiency in athletic youth. Ceiling effects in retained tasks limit diagnostic usefulness, while time-based dynamic tasks provide better differentiation. Moreover, Principal Component Analysis results justify categorizing tasks into distinct domains and aligning assessment strategies with sport-specific requirements. These insights contribute to ongoing efforts to optimize athlete-centered motor assessments. Selecting tasks with sufficient challenge, consistent reliability, and strong construct validity is essential for evaluating young athletes accurately. Prior studies such as those by Strooband and colleagues reinforce the need for task refinement and validation, especially when adapting tests for sport-specific applications (22). The adapted BOT-2 employed in this study remains exploratory and requires further validation before clinical or large-scale implementation. Despite the intrigue results, due to the small sample size (n=10), the statistical power can be questioned as well as limitation to generalize towards bigger and other population.

5. CONCLUSION

Tasks with low variability, especially those failing to differentiate skill levels, require important adjustments. Increasing the difficulty of these less variable tasks while retaining those with greater spread would improve the test's capacity to assess motor and cognitive integration. Descriptive and composite analyses suggest that fine motor tasks (e.g., Drawing Lines, Folding Paper) present strong ceiling effects, while adapted, time-based tasks such as Dribbling, Jumping, and Coin Transfer reveal greater sensitivity. When used with young athletes in developmental environments, these changes enhance test precision and reliability. Additionally, Principal Component Analysis and correlation matrix findings reinforce that motor proficiency is a multidimensional construct, with some motor domains (e.g., balance-related precision) emerging as uniquely intertwined. Refining subtests around these clusters will better capture specific motor demands tied to athletic development.

Future studies should test larger, more diverse athlete samples to further improve the generalizability and construct validity of the test. Comparative work should explore whether sport-specific adaptations of the BOT-2 can reveal distinct motor profiles in agility-driven (e.g., soccer), coordination-intensive (e.g., gymnastics), or precision-focused (e.g., archery) disciplines. Normative sport-specific data will allow for benchmarking and personalized training interventions, supporting a stronger foundation for performance profiling, talent identification, and motor development tracking in sport science.

AUTHORSHIP CONTRIBUTION STATEMENT

Muhamad Izzan Ismail: conceptualization, design, data acquisition, data analysis, writing – original draft; Mohd Syafiq Miswan: study design, data acquisition logistics, data analysis; Hosni Hasan: conceptualization, writing – review & editing; Nurul Farha Zainuddin: data interpretation, design, project administration, writing – review & editing; Mohd Irzat Rozaidy, Mohamad Roseli and Farith Zaris Erfan Zeini Effendey: data collection.

DATA AVAILABILITY

Data is available within the article or its supplementary materials.

DECLARATION OF COMPETING INTEREST

There is no conflict of interest in this project.

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