Feasibility and validity of the PERF-FIT Test Battery: a tool to measure motor performance and anaerobic fitness in young children across low-income settings.

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Abstract
Background Despite the global interest in promoting physical activity and fitness among school-aged children, few valid and reliable assessments exist to measure motor performance and anaerobic fitness in young children across low-income settings. The aim of this paper is to describe the development and validation of the Performance and Fitness (PERF-FIT) test battery, a new assessment of skill-related physical fitness for children in low-income settings.

Method The PERF-FIT test battery was developed using a stepwise process including defining the domains of the construct, selection and evaluation of test items and pilot testing. After the developmental process, feasibility of implementation in resource-limited schools and content validity was examined. The Content Validity Index was used as an estimate of the content validity per item and for the total battery. Next structural validity was assessed in a sample of eighty (n=80) Brazilian children aged 7-12 years using principal component analysis.

Results Findings suggest that it is feasible to implement the low cost PERF-FIT in resource-limited schools. The Content Validity Index (CVI) for the Throw and Catch item was 0.86 and 1.00 for the other nine items, leading to a total CVI score of 0.99. The hierarchical sequence of the item series was confirmed by highly significant (p <0.001) linear trends, confirming the increase in difficulty of subsequent items. Principal component analysis revealed three factors; the first component is represented by Locomotor skills that require static and dynamic balance, the second component by Throwing and catching items and the third component by Agility and power items.

Conclusion The PERF-FIT test battery is easy to administer and suitable for measuring performance-related physical fitness in school-aged children living in low-income settings. It has excellent content validity and good structural validity. After minor adaptions the PERF-FIT test battery is ready to gather normative values on skill-related physical fitness in young children in low-income settings. More research is needed to evaluate its reliability as well as criterion and cross-cultural validity.

Background
For decades, physical fitness has been recognized as a powerful indicator for good health in children and adolescents [1–3]. High levels of physical fitness are believed to normalize weight and enhance
mental health in children [4]. Good levels of gross motor skills and physical fitness also provide the basis for participation and allows children to perform everyday tasks [5]. As a result, there is a global push for physical activity and fitness surveillance in young people at the population level [2,3,6]. This increased focus is also reflected in recent data, which suggest drastic decline in physical fitness levels of children across the globe [7].

Despite the expanding interest in physical activity [8], there seems to be limited data on children’s motor performance and physical fitness in many low- and middle-income countries. Specifically, there is lack of data on skill-related physical fitness, a concept that combines motor skill performance and anaerobic fitness. This may partly reflect the lack of accessibility to standardized test batteries that are affordable and easy to administer across cultures in low-income settings. Such tests are needed to assess children’s skills and functional performance and to generate quality data for policy development, intervention and evaluation of children which poor motor skills and fitness.

Numerous test batteries have been developed to assess physical fitness in children [9–10]. A review of the literature suggests that the Eurofit, Alpha and Fitnessgram test batteries have been extensively used among children and adolescents worldwide [10, 11, 12]. However, these tests concentrate on health-related physical fitness such as cardiorespiratory endurance, muscle strength and flexibility.

None of these tests focus exclusively on performance- or motor skill-related physical fitness attributes (e.g. jumping, throwing and catching, balance and agility), which are considered to be critical for children’s physical activity in everyday life [13]. In addition, previous motor performance and physical fitness tests were primarily developed in Western populations. In this area of research, little attention has been paid to children with and without motor delays in low resource settings. To address this gap, we developed a new field-based test called the Performance and Fitness (PERF-FIT) test battery. The PERF-FIT was designed to measure skill-related physical fitness in children with and without motor problems (e.g. Developmental Coordination Disorder (DCD), Attentional Difficulty Hyperactivity Disorder (ADHD), or Fetal Alcohol Syndrome (FAS) Learning Disabilities (LD) and to gather new data on children’s performance in low resourced communities in Africa and South America. The aim of this paper is threefold (1) to describe the development of the test, (2) to describe the feasibility of
implementing the test and (3) to examine content and structural validity using initial data collected from 7-12-year-old children living in Brazil.

**Methods**
This section will be presented in two phases (See Figure 1). Phase one will provide a description of the PERF-FIT and explain the steps taken to develop the test items. In the second phase, we will provide preliminary evidence to support the feasibility and validity of the test.

<Insert Figure 1 about here>

Phase 1: Test description and development

*Description of PERF-FIT*

The PERF-FIT was designed as an instructor-administered, cross-culturally comparable, functional measure of skill-related physical fitness for children aged 6-12 years. The main rationale was to develop a low-cost, and easy-to-administer measure that could be used across a variety of low-income contexts. The PERF-FIT focuses on skill-related physical fitness and is divided into two subcomponents; *motor performance* and *agility and power* subscale.

**Motor performance subscale.**

The motor performance component or the *skills item series (SIS)* consists of five items including jumping, hopping (left and right), bouncing and catching, throwing and catching, and balance. These tasks are administered to the child in an increasing order of difficulty (task loading). The child starts at the easiest level and ends at the most difficult level within the same task series. The items within a particular task/skill series are terminated when the child is unable to achieve the minimum points after two consecutive trials. No second trial is performed when the maximum points are attained. For example, in the jumping task series, distance and height are modified to increase the difficulty level of the task after the initial trial. Each child is given a practice trial before performing the test trials. To avoid fatigue 15 seconds is allowed between trials. The child’s performance during the test trials are recorded and used for calculating the item score (See additional file A for items and scoring).

**Agility and power subscale.**

The agility and anaerobic power component has five items. These are running, stepping, side-jump, long jump, and overhead throw. All items are initially demonstrated before the child is asked to perform one practice trial. Following this, each child is expected to perform two test trials, with 15 seconds rest interval. The child’s performance during the test trials is recorded and best scores are used in the analysis.
**Developmental process**

The development of the PERF-FIT involved a three-step process and included (1) development of a conceptual framework (2) selection of initial item set and expert evaluation and (3) pilot testing.

**Conceptual framework.**

A literature search was first conducted to define the domains of the core skill-related physical fitness domains that were thought to be important for children’s development and growth. Based on our search, six key skill-related physical fitness domains were identified including agility, power, balance, coordination, speed and reaction time and examples of items adequate per domain were described (Table 1).

**Table 1. Definitions used for the domains of skill-related physical fitness (adapted from Caspersen, Powell &Christenson, 1985).**

| Domain      | Theoretical definitions                                                                 | Operational definitions                                                                 |
|-------------|----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Agility     | The ability to rapidly change the position of the entire body in space, with speed and accuracy. | The child is asked to jump side to side at high speed and with great efficiency.         |
| Balance     | The maintenance of equilibrium while stationary or in motion.                          | The child is asked to stand on one leg while holding on to his free foot for an extended period of time (static). The child is asked to grasp his/her unsupported foot while making slow steps in the agility ladder (dynamic) The child is asked to move his arms and trunk forward to pick up an empty can while standing on one leg. The child is asked to time arm and leg movements to perform a catch or make consecutive jumps smoothly. |
| Coordination| The ability to use the senses, such as sight and hearing, together with moving body parts, in performing motor tasks smoothly and accurately. |                                                                                           |
| Power       | The rate at which a person can perform work (strength over time).                       | The child is asked to apply great force to a heavy object to make a throw or propel the whole body forwards to make a long jump. |
| Speed       | The ability to perform a movement within a short period of time.                        | Running speed is tested in the agility ladder where the child is moving forward from the start line quickly to the end of the ladder, turn and run back. |
| Reaction time| The time elapsed between a stimulus and the beginning of the reaction to it.            | Most items have a start signal to which the child has to respond; many adaptation made to make a movement successful are based on rapidly responding to a stimulus and adapt the movement to that stimulus to avoid stepping on a bar (agility items) or estimate the trajectory of a bouncing or thrown ball. |

These domains were selected because of their cross-cultural applicability, relevance to childhood
routines and games, ease of testing in schools in low-income settings and their ability to enhance performance across the lifespan. In addition, we wanted to ensure that the relationship between (anaerobic) fitness and motor skills is acknowledged in diverse low-income communities [14] and to create more awareness that evaluation of skills-performance related physical fitness has important implications for child development, physical education and policy decisions [15].

Item identification.

Based on the literature search and pre-defined criteria (see Table 2), twenty items representing the six core domains were identified and reviewed by a panel of experts (experienced researchers and practitioners). Based on the experts’ feedback, ten items were finally included in the PERF-FIT test battery. The ten items were divided into two subscales (i.e. motor performance and agility and power components) as described earlier. The theoretical and operational definitions of each domain were clarified to guide task identification. Further, the process of increasing the difficulty of tasks (task loading) for each item was defined to facilitate implementation and interpretation of scores. (See Additional file 2 for the items and the increase in difficulty).

Table 2. Criteria for selecting items of the PERF-FIT test battery.

| Criteria | Description |
|----------|-------------|
| A        | Tasks should be able to measure skill-related physical fitness. |
| B        | Tasks should allow for progressive increase in difficulty (i.e. task loading). |
| C        | Tasks should have cross-cultural applicability and be appropriate for children aged 6-12 years |
| D        | There should be no specific space restrictions for testing |
| E        | Materials needed for the test should be low-cost. (See Additional file 3) |

Pilot testing.

The last phase of the development of the PERF-FIT was the pilot-testing phase. The final items were tested in two small samples of South African children (n=10 and n=20) to assess feasibility, acceptability, ease of administration and implementation challenges. Feedback that was obtained from the children and test administrators in the pilot samples were used to refine aspects of the test items, details in the instructions and the scoring forms to reduce the burden of administration (for an example of an item description see Additional file 2). Instructions for obtaining the standardized materials were also provided in the manual (see Additional file 3).

Phase 2: Validation

*Feasibility*
The feasibility of the test was assessed by looking at 1) acceptability (based on participants and assessors’ perspectives), 2) adverse events or injuries 3) burden of administration - set up and administration time, cost, equipment, space and training requirements. The experiences of the assessors were also captured by self-report.

Content validity

Seven experts (all experienced clinicians with doctorate degrees; three from Africa, two from South America, and two from Europe) assessed the relevance of the PERF-FIT items. Experts were required to indicate whether the PERF-FIT items reflected the constructs they were intended to measure. In addition, they were asked to evaluate the appropriateness of the selected tasks for the target population (typically developing children and children with poor motor coordination, e.g. Developmental Coordination Disorder (DCD), Attentional Difficulty Hyperactivity Disorder (ADHD), or Fetal Alcohol Syndrome (FAS) Learning Disabilities (LD), in low-resourced communities). This evaluation was done using a 4-point scale developed based on the criteria proposed by Davis [16] (Score 1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 = highly relevant). The Content Validity Index (CVI) was used as an estimate of the content validity of each variable in the test battery. Additionally, Scale-level Content Validity Index (S-CVI), representing the overall content validity of the PERF-FIT, was computed as the average of the I-CVIs for all the test items [17].

Structural validity

The PERF-FIT test was validated in 80 Brazilian children aged 7-12 years (mean 9.2 SD 1.1). Participants (39 boys; 41 girls) were recruited from two primary schools in a low-socioeconomic area in the state of Sao Paulo. Children were excluded if they had any injury or physical disability that hindered their involvement in the assessments. Written informed consent was obtained from parents and each child provided assent before involvement. Ethical approval was obtained from the Human Research Ethics Committee of the Federal University of Sao Carlos (89993118.8.000.5504/2018). Permission was also obtained from the head teachers of the schools.

The PERF-FIT was administered by a team of trained assessors (i.e. physical therapists and a physical education teacher). Testing took place in the school premises and children were assessed in pairs. However, in situations where children were too distracted or absent from school, they were tested individually on a separate day. Data collection was completed within a space of three weeks. Structural validity was evaluated by testing the linear increase of the loading used to make the items
more difficult (see Additional file 1) and by exploratory factor analysis on the data of the 80 children.

Statistical Analysis

Descriptive statistics such as means, standard deviation, and frequencies were used to summarize the data and experts’ responses. The Content Validity Index (CVI) was used as an estimate of the content validity of each variable in the test battery. CVI is the most widely used quantitative approach for the content validation of instruments. Specifically, Item Content Validity Index (I-CVI) was computed for each test item as the number of experts giving a rating of either 3 (quite relevant) or 4 (highly relevant), divided by the total number of experts in the study. Scale level-Content Validity Index (S-CVI), representing the overall content validity of the PERF-FIT, was computed as the average of the I-CVIs for all the test items. The adopted cut-off for an acceptable level of I-CVI was >0.78 and S-CVI of greater than 0.90 qualifies the test battery for excellent content validity [17].

Further, structural validity of the SIS was checked by examining the hierarchical sequence of the items visually, and by repeated measure ANOVA. In order to test for linearity, maximum scores for the easier items of jumping, hopping and balance were divided by 2 to make the maximum score for all items equal (i.e. 4 points). Structural validity was also examined by exploratory factor analysis. A principal component analysis (PCA) with Varimax rotation with Kaiser-Meyer-Olkin test was performed. Eigenvalues greater than one were used to determine the number of dimensions in the PERF-FIT. Data analyses were performed using SPSS (version 24.0, SPSS Inc., Chicago, IL, USA).

Results

Feasibility

Acceptability

Acceptability of the PERF-FIT test was high, both the participants and assessors liked the test items. Participants demonstrated great understanding regarding how the task difficulty was increased in the SIS, which was consistent for jumping and hopping items. If a participant could not make the jumps or hops over the foams, they jumped on them or scattered them and in most cases they helped with rearranging the materials for the next trial. Only one participant out of the eighty fell during testing, and some participants complained of tiredness if they had to execute two trials (first and second trial) but no injuries were observed. All but one child was able to perform all the test items. That child
complained of pain in his right knee during the hopping tasks. Two children needed extra recovery
time because they ran out of breath after completing the agility tasks. One girl had severe fear of
failure and needed extra encouragement to finish the test. Another girl had strong reading glasses
and needed to take them off because moving made her “dizzy”. Lastly, most participants were not
comfortable with the stork balance item. This was because touching their stance leg with the other
foot sometimes made their trousers dirty. Twenty-four percent (24%) of the participants performed
the test without shoes because they lacked the appropriate footwear for running or jumping. In 41%
of the items of the skill item series, participants obtained the maximum score during the first trial on
the given task. However, 11% of the participants were still able to obtain the maximum scores during
the second trial (ranging from 3% extra maximum scores on the left to 18% on the right foot for the
balance item; for the jump and hop items, the percentages varied from 9 to 14%). Asking participants
to re-take an item in cases when the maximum score was not obtained was found to be acceptable
for the majority of the participants. However, in situations when a child scored just enough points on
an item after the three trials (one practice- and two test trials) in a row on two difficult levels, the
hopping items were reported to be quite tiring, although the children alternated the right and left legs
and were allowed 15 s rest interval.

Adverse effects or injuries

As previously indicated, the participants were able to complete testing procedures without reporting
injuries. Also, no adverse events or complications were observed by the assessors during and after
testing. Though children showed some short lasting signs of tiredness, which fits into the intended
construct to be measured, a greater proportion of participants completed the tasks without getting
exhausted.

Burden of administration

It was observed that the time needed to complete the test depended on the participant’s skill level.
Overall, it took approximately 20-40 minutes to complete the full test per child. If the child is only
able to do the first level of the SIS, less than 20 minutes was needed. If two children were tested at
the same time, it took about 30-50 minutes to complete all items because items only had to be
demonstrated once and children could alternate so they had the required rest between items. Also, it
took about 10 minutes for the assessors to set up and to pack the test materials. The test forms were
easy to fill out, not many disputable situations occurred, as reported by the assessors. Mistakes made
by the children were usually easy to identify (e.g., missing a catch, losing balance, jumping on the
foams, or stepping on the bars of the ladder). The equipment was found to be relatively cheap (less
than 50 US dollars). Just a firm surface was needed for testing and the dimensions were 5-6 meters long by 3-4 meters wide. Assessors were encouraged to walk along the agility ladder with the child to be able to check if the child stepped on the bars whenever the foams were used. The pieces of foam were found to be bulky (though light) for transportation to the different schools.

Content validity
The median score for all the questions on the relevance of constructs and items for target group was four. All the experts deemed the five SIS “quite relevant” or “highly relevant” in measuring motor skills performance. The same trend was evident for agility and power items. One therapist scored a 2 for “throwing and catching” because she had preference for manual dexterity items instead of throwing and catching.

The experts were unanimous in their responses regarding the relevance of the items for the target population. Five deemed the items “highly relevant” in measuring the constructs of interest in children in low-income settings. Two experts chose the “quite relevant” more often than “highly relevant”.

I-CVI for the Throw and Catch item was 0.86 and 1.00 for the other nine items, leading to a S-CVI of 0.99, indicating excellent content validity.

Structural validity
Hierarchical sequence of the items was depicted by plotting the mean score over the same tasks with increasing difficulty. Figure 2 a, b and c show that scores decrease with increasing difficulty. For the entire SIS (jumping, hopping, bouncing and dynamic balance) the repeated measures ANOVA confirmed this decrease in scores was highly significant ($p<0.001$) and linear. It was only in the case of throwing that the mean for catching after a clap with two hands was found to be easier than to catch with the non-preferred hand without a clap. As depicted in 2b it was clear that the increase between the two dynamic balance tasks and the “Can” tasks was large which was confirmed by a higher order polynomial effect ($p<0.001$).

A principal component analysis was performed with 13 item variables (see Table 3) and Varimax rotation. The Kaiser-Meyer-Olkin test showed that the sample size was adequate for performing a PCA (KMO = 0.85) as recommended by Hutcheson and Sofroniou [18]. Bartlett's test of sphericity was significant, showing a sufficiently high correlation between the variables for a PCA. Three components
had eigenvalues above the Kaiser's criterion (Eigenvalue of greater than 1) and could together explain 63.5% of the variance. The factor loads on the components suggest that the first component is represented by "Locomotor skills that require static and dynamic balance", the second component by "Throwing and catching" and the third component by "Agility and power " (see Table 3). Throwing the heavy bag loaded with the other ball skills not with the agility and power. The normal running in the agility ladder loaded on both Locomotor and Agility factor.

Table 3. Factor analysis of the PERF-FIT items, values over 0.40 are shown in the columns.

| Rotated Component Matrix<sup>a</sup> | Component     | Locomotor/Balance | Object control/Ball skills | Agility/power |
|------------------------------------|---------------|-------------------|-----------------------------|---------------|
| 1. Jump                            |               | .746              |                             |               |
| 2. Hop Right                       |               | .770              |                             |               |
| 3. Hop Left                        |               | .721              |                             |               |
| 4. Static Balance Right            |               | .741              |                             |               |
| 5. Static Balance Left             |               | .528              |                             |               |
| 6. Dynamic Balance                 |               | .631              | .458                        |               |
| 7. Bounce and Catch                |               |                   | .797                        |               |
| 8. Throw and Catch                 |               |                   | 711                         |               |
| 9. Overhand throw                  |               |                   | .762                        |               |
| 10. Long jump                      |               | .410              | .434                        | .434          |
| 11. Running                        |               | -.533             | -.493                       | -.493         |
| 12. Stepping                       |               |                   | -.796                       |               |
| 13. Side Jump                      |               |                   | .851                        |               |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Discussion

The purpose of this study was to describe the development, feasibility and validation (content and structural validity) of the PERF-FIT battery, a new measure of skill-related physical fitness designed to be used across low-income settings. Our hope is to use this test battery to gather quality data on children's motor skills and physical fitness at the population level in low-resourced communities, where motor performance assessments have historically received little attention. Overall, the PERF-FIT was found to be feasible and implementable in a low-resourced context. Additionally, the test was
deemed to have excellent content and good structural validity. Structural validity was confirmed with exploratory factor analysis revealing three factors. The PERF-FIT test battery does not only assess different motor skills (for instance locomotion combined with stability) but also evaluates motor coordination and anaerobic power, which are embedded in different skill sets (for instance hopping 4 times sequentially over foams with a height of 10 cm or throwing a 2 kg sandbag). Since the PERF-FIT is intended to measure skill-related physical fitness, the way it is structured appears to be more appropriate than testing coordination and power in isolation. The three factors (Locomotor skills and balance, Throwing and catching, as well as Agility and power) that emerged in the factor analysis confirmed that the PERF-FIT is suited for measuring three major aspects of motor behavior in children. An unexpected finding was that the explosive power item (long jump) and dynamic balance clustered with the object control items (balls and heavy bag) albeit with lower loading. Future studies may have to confirm the common denominator for these skills.

Evidence-based intervention approaches for children with poor motor skills such as task-oriented training tend to focus on the meaningful tasks, and cultural and contextual demands of a given task [19]. Since we intended to develop a new low-cost test, we also tried to make a more task-based gross motor test for school aged children by measuring different levels of the same task (Skill Item Series). We also added components of anaerobic power and agility to make the test comprehensive enough to assess relevant motor skills and fitness variables needed for optimal child functioning. Another reason was to provide a test that will align with the new guidelines on assessment and intervention for children with DCD [19]. Failure of anaerobic power and agility may have detrimental effects on children’s participation at the playground, home and in their communities.

The PERF-FIT has cross-cultural applicability and can be used in diverse resource-limited environments. The test battery could be administered outside when the weather is good or inside on a rainy day. The acceptability of the test seems to be good both for the children and the assessors. Because some assessors experienced challenges demonstrating the more difficult items, we have developed instructional video clips that can be used to train to assessors and can be shown on a phone or as pictures to the children. However, it was clear that after children were shown the easiest
level of the SIS, the harder items did not have to be demonstrated because the children implicitly knew the next level of the task.

This study revealed that some minor adaptations are needed. Foam blocks will be made smaller without changing the task difficulty. We will use half the width in our next validation study. Because children complained of dirt on their trousers after doing the stork balance task, we will add the standing knee pose (comparable to the standing knee pose on the Wii balance board; to replace the stork balance task) [20, 21]. To avoid to much fatigue, we will increase the number of points that children need to attain before proceeding to the next difficultly level. We therefore intend to increase the number of points that children need to obtain to go to the next level from 50 % to greater than 50%. After these adaptations we have started collecting normative data in areas for which the test is meant to be used.

**Strength and limitations of the study**

In accordance with the COSMIN guidelines [22], we sampled data from a group of children in one of the targeted low-resourced areas and involved the potential users (researchers and clinicians) in the development and evaluation of the test items on relevance and suitability for the target population. 

Pilot testing was conducted and a relatively large sample was tested to evaluate feasibility and aspects of validity in a typical low-resourced community. Assessors reported the test was easy to administer and the time required to administer the tests was reasonable (i.e. maximum 40 minutes per child). We had no safety issues, adverse effects or injuries.

A limitation of the study is that the data were derived from only two schools and testing was performed during the hot season, which may have influenced children’s performance. This limits the generalizability of the findings of this validation study. Moreover, no 6-year-old child participated in this initial study. Younger children may be more likely to be distracted and may not understand the test items as easily as the seven-year olds. Lastly, the results need to be confirmed in diverse cultural contexts in Africa and South America as well as in specific populations including children with DCD, ADHD, underweight, obesity or learning disabilities.

In summary, the PERF-FIT test battery seems to be feasible and implementable in low-resourced
communities. The test is viewed to have relevant items, and possesses excellent content and good structural validity and could be applied in many low-income settings to monitor and track children’s skill-related physical fitness.

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Declarations

Contributors BCMS-E originally developed the concept and initial design of the instrument used in the study. DJ acted as the lead investigator during her stay in Brazil. JN, recruited research assistants and participants with variable assistance coming from other people who were acknowledged in the acknowledgment section. BCMS-E, JD and JN trained the research assistants and supervised the data collection. BCMS-E drafted the manuscript for publication and acted as the corresponding author. EB performed the literature search and several critical revisions of the manuscript, statistical input, and together with BCMS-E, DJ and JN who all provided extensive suggestions for revisions prior to submission to the journal for review. All the authors read and approved the final version of the manuscript.

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**Competing interests** None declared.

**Patient and public involvement statement** This research was done without patient involvement.

**Ethics approval** Ethical approval was obtained from the Human Research Ethics Committee of the Federal University of Sao Carlos (89993118.8.000.5504/2018). Consent was obtained via the parents and assent was signed by the children. Permission was also obtained from the head teachers of the schools.

**Data availability statement** The PERF-FIT manual and instruction videos can be accessed free of charge after registration via the first author for use in low resourced communities.

**Figures**

Figure 1

Steps in the development and validation process of the PERF-FIT.
Figure 2

Mean scores on the Skill Item Series; a) Jumping and Hopping, b) Balance and c) Ball Skills.
Supplementary Files

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