Developing a School-based Screening Tool for Identifying Adolescents with Low Motor Coordination Abilities

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Abstract

This study sought to select the most relevant test items from the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-2) and from a selection of health-related fitness tests for identifying school teenagers with poor motor coordination. The 241 participants in this study (144 boys, 97 girls aged 13-14 years old) were tested on the short form of the BOTMP-2 and on the following additional fitness tests: (a) seated Medicine-ball test, (b) broad jump, (c) handgrip strength, (d) alternate hand ball wall toss, (e) 10 x 5-m agility shuttle run, and (f) Chester step test. We performed a factor analysis of participant scores on these various tasks and BOTMP-2 test items to reduce them to the least number of meaningful and useful items. Four factors explained 45% of the data variance : "gross motor skills and power" (including broad jump, hand ball toss, shuttle run, and sit-ups tests), "fine motor skills" (including copying star, following the maze and paper folding), "core strength and balance" (including push-ups, hopping and balance beam), and "general body strength" (including medicine ball throw and handgrip). We conclude that an efficient school-based battery of test items to screen 13-14 year old adolescents for fitness and coordination should assess these four factors, and might especially rely upon the broad jump, copying a star shape, hopping handgrip strength, aerobic fitness and wall ball toss.

Key words: gross motor skills, fine motor skills, strength, balance, factor analysis.

Introduction

Approximately 5-6% of school-aged children and adolescents in Europe experience significant motor control and coordination difficulties (Gillberg & Kadesjo, 2003). These children and adolescents are less likely to be involved in general play and organized sports not only during childhood but also later in life (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009). Decreased levels of PA associated with poor motor coordination in these children and adolescents could compromise their overall health and well-being, with poor musculo-skeletal fitness (Cantell, Crawford, & Tish Doyle-Baker, 2008), and a higher risk of developing cardiovascular disease (Rivilis et al., 2011) and anxiety and depression (Cairney, Rigoli, & Piek, 2013). This worrisome profile highlights the need to identify and address poor health-related fitness and PA participation in this population.

Several school-based exercise interventions have been developed to engage children and adolescents with poor motor proficiency (Smits-Engelsman et al., 2018), relying on their diagnosis through a variety of standardized motor competence batteries of tests, such as the Movement Assessment Battery for Children (MABC-2, Henderson, Rose, & Henderson (1992)), the Test for Gross Motor Development (TGMD-2, Issartel et al. (2017)) or the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-2, Bruininks (2005)). These tests assess a range of motor proficiency aspects, including mainly manual dexterity and fine manual control, body coordination, gross motor skills, aiming and catching, locomotor skills, balance and object control and categorize participants according to precise criteria for clinical and research purposes (Geuze, Schoemaker, & Smits-Engelsman, 2015). Some of them are process-orientated while other are focused on the product (Logan, Barnett, Goodway, & Stodden, 2017). However, in school or sport settings in which broad categorizations are the goal, there is less need for such precision and a deviation from this specific criterion-based approach may be of greater benefit (Geuze et al., 2015). In their current form, these diagnostic tools are lengthy, labour intensive and require clear and closely followed instructions, compromising their efficiency for mass screening (Bruininks, 2005). In addition, some test items are highly prone to a ceiling effect (Brahler, Donahoe-Fillmore, Mrowzinski, Aebker, & Kreill, 2012), highlighting the need for a closer examination of each item for its relevance to large scale school-based testing, in order to reduce testing time and increase assessment efficiency.

Health-related fitness test batteries are also frequently involved in school-based exercise interventions targeting children and adolescents with or without poor motor proficiency to categorize them at the start of the intervention and assess any benefits linked to exercise (Ortega et al., 2008; Vanhelst, Beghin, Fardy, Ulmer, & Czaplicki, 2016). It is interesting to note that many of the tests involved in these large batteries, assessing strength, power, speed, agility, muscular endurance or cardiorespiratory fitness, also heavily rely on coordination. For example, Hands (2008) highlighted that the fitness components of jumping involve very specific elements of motor control, such as precise timing and positioning of the limbs during the different phases of these skills. However, some tests include more coordination elements than others do; for example, agility performance relies more on coordination than straight-line speed, and assessing cardiorespiratory fitness with the Chester Step test is more demanding in terms of coordination than the Cooper (12-min run test around a stadium) test. In the context of youth testing, fitness tests involving more coordination might be more interesting as they replicate the context in which they play and interact with others.

Several studies have attempted to categorize health-related fitness or motor competency tests into separate factors, either to assess the validity of these test items in the context of performance or to adapt testing to time constraints, such as those associated with large scale school screening (Brown, 2019; Hassan, 2001; Issartel et al., 2017; Kambas & Aggeloussis, 2006; Psotta & Brom, 2016). However, past studies have considered either motor or health-related fitness test batteries, while there is currently no study, to our knowledge, that has examined both types collectively. In addition, many of the above-mentioned studies were performed on young children, while few have addressed adolescents in this context. It is crucial to examine this population as there is a well-established decrease in physical activity levels at this age, widening the gap in health-related fitness between adolescents with and without coordination issues (Schott, Alof, Hultsch, & Meermann, 2007). Therefore, the present study aimed to select the most relevant tests from amongst a selection of motor coordination and health-related fitness tests with the goal of assisting mass screening in schools to identify adolescents with poor motor coordination.

Method

Participants

Two hundred and forty-one adolescents (144 boys, 97 girls) aged 13-14 years (year 9 in school) participated in this study. They were recruited from a mainstream school in the Oxfordshire area, classified in the 2nd quintile of economic deprivation with a score of 13.03, based on the Office of National Statistic Indices of Multiple Deprivation 2010. Participants were mainly Caucasian, and 15.4% were overweight according to the World Health Organisation (WHO) cut-offs for body mass index (BMI, kg.m^{-2}) for this age group (de Onis et al., 2007). We obtained permission to collect data from each school's head teacher, and parents or legal guardians returned a signed consent form to exclude their child from the study after details about the study procedures were sent to them. This opt-out recruitment method was approved by Oxford Brookes University Research Ethics Committee at the time of the study.

Design Overview

Data collection took place in the sports hall of each school during physical education (PE) classes, in the form of a circuit of various stations overseen by PE teachers. Tests within this fitness test battery included the Bruininks-Oseretsky Test of Motor proficiency (BOTMP-2) short form, as well as a selection of health-related fitness tests. Participants were randomly divided into groups of six, each of which rotated between stations.

Tests

The short version of the BOTMP-2 is a popular motor assessment battery used for clinically identifying movement difficulties in children and young people between the ages of 4-21 years (Bruininks, 2005). The BOTMP-2 is characterized by excellent inter-rater reliability (r: 0.88-0.92), good test-retest reliability (r: 0.62-0.73), (Lucas et al., 2013), and moderate to good levels of agreement (validity) compared to similar tests (Fransen et al., 2014). The BOTMP-2 consists of eight subtests including a total of 14 items for the assessment of fine motor precision (drawing lines through paths-crooked, folding paper), fine motor integration (copying a star shape, copying a square shape), manual dexterity (transferring pennies), bilateral coordination (jumping in place same side synchronised, tapping feet and fingers same side synchronised), balance (walking forward in a line, standing on one leg on a balance beam with eyes open), running speed and agility (one-legged stationary hop), upper-limb coordination (ball dropping, ball dribbling) and strength (push-ups, sit-ups). The set-up, instructions and scoring system of each of the items are described in detail in the BOTMP-2 manual (Bruininks, 2005).

Past literature documents the use of a variety of health-related fitness tests as part of large assessment batteries, covering mainly strength, power, speed, agility, balance, flexibility, muscular endurance and cardiorespiratory fitness (A Kambas & Venetsanou, 2014; Ortega et al., 2008; Vanhelst et al., 2016). We chose tests for this research based on their requirement for coordination as well as fitness. On these bases, as well as time constraints, we selected no measures of flexibility or speed, as we believed that those tests relied less on coordination than did other tests. We also excluded tests of muscular endurance and balance to avoid redundancy with measures within the BOTMP-2 short form.

The seated medicine ball throw assesses upper-limb power and was selected for its ease of implementation and its coordination requirements (compared to the bench press for example). The medicine ball throw required participants to sit on the floor with legs fully extended, feet (~60 centimeters) apart and their backs against a wall. A four killogram medicine ball was held with the back of the hands facing the center of the chest and the forearms parallel to the ground.

Participants were instructed to throw the medicine ball (by pushing the hands away from the chest) vigorously as far straight forward as they could, while keeping their back against the wall. We then used a measuring tape to acquire the distance thrown (from the wall to where the ball landed), and we recorded the best distance achieved out of three trials recorded. This task has shown very good test-retest reliability in children and adolescents in its past usage (intraclass correlation coefficient [ICC] of 0.93, (Vanhelst et al., 2016).

The broad jump is among the most commonly used measures of lower limb power in children and adolescents; we chose it, rather than a vertical jump test, for its ease of implementation and cost-effectiveness. The broad jump is characterized by very good reliability (Test-retest ICC of 0.91, standard error of measurement [SEM] of 12.23 and coefficient of variation [CV] of 6.89%,) (Gillen, Miramonti, McKay, Leutzinger, & Cramer, 2018). Participants started in a standing position with feet together behind the start line on a jumping mat. They then jumped horizontally as far as possible. We measured the distance between the starting line and the heel of the foot that was most backward, and we kept the longest jump of two trials.

We assessed handgrip strength of the dominant hand (the one used for writing) using a handgrip dynamometer (Takei 5001, Tokyo, Japan). We chose this test because it is quick to administer and is a good predictor of total body strength (Wind, Takken, Helders, & Engelbert, 2010). In a standing position, we instructed participants to squeeze as hard as they could while simultaneously swaying their arm down in front of them, and we recorded the best of two trials. Past researchers have reported excellent test-retest reliability for this test (mean inter-trial difference of 0.3 [*SD* =2.5] and 0.0 [*SD* = 1.8]) for boys and girls, respectively (Ortega et al. , 2008)).

The alternate hand wall toss is a relatively new test of upper limb coordination (Du Toit, Krüger, Fowler, Govender, & Clark, 2010) consisted of standing one meter way from a wall and tossing a tennis ball with one hand against the wall in an underarm manoeuver and then catching it with the opposite hand. The ball was then thrown back against the wall with the hand that caught it, and, then, it was caught again with the initial throwing hand. The test continued for 30 seconds and we recorded the number of successful catches.

We assessed agility with the 10 x 5-meter shuttle run (Baquet, Berthoin, Gerbeaux, & Van Praagh, 2001). The number of 180° turns in the 10 x 5 meter shuttle requires more coordination than other agility tests. Participants started with one foot directly behind a line traced on the floor, and we instructed them to run and step on an opposite line placed 5-meters away, turn and then run back to the starting line. This was repeated five times, and we recorded the duration (in seconds) required to run these 50 meters. Prior researchers have reported good test-retest reliability for this test (r=0.69; Baquet et al. (2001)).

The Chester step test is a sub-maximal multi-staged fitness test that consisted of stepping on a 30 centimeter high step (The Step, USA) at a gradually increasing frequency (15-35 cycles per minute) set by a metronome for five stages of two minutes each (Buckley, Sim, Eston, Hession, & Fox, 2004). We chose this test because of its high reliance on coordination and for its minimal space requirements. One cycle is defined as stepping on and off the step with both feet. The test started with a brief introduction that familiarized the participants with the task, followed by a demonstration of the initial stepping rate. Throughout the test, we encouraged participants to step at the appropriate rate. We measured heart rate (HR, beats.min^{-1}) during the last few seconds of each stage, using a pulse oximeter and expressed results relative to each participant's theoretical maximal HR (HR_{max}=220-age). We then used the five HR readings for each participant to predict maximal oxygen consumption (VO_{2max}), based on the extrapolation of a line of best fit, which passes through HR readings for each stage, up to a level equal to the participants' estimated HR_{max} (Buckley et al., 2004).

Statistical analyses

We conducted all statistical analyses with SPSS 23 for Windows (SPSS Inc, Chicago, IL, USA). We calculated participant means and standard deviations on all test scores. Subsequently, we ran a factor analysis to reduce the test items to the least number of meaningful and useful items. The extraction method chosen was Principal Axis Factoring, and the rotation method was oblique "Oblimin" with Kaiser Normalisation. An oblique rotation allows the selected factors to be correlated with one another. We used the Kaiser-Meyer-Olkin (KMO) statistic to test for sampling adequacy, with values less than 0.5 indicating that sampling was not adequate for factor analysis (Rosenblad, 2009). In order to determine the number of underlying factors in the data set, we ran an initial analysis to obtain Eigen values for each factor. Eigen values represent the amount of variance explained by a factor. We included only factors with Eigenvalues above Kaiser's criterion of 1 (i.e., a substantial amount of variation) (Rosenblad, 2009). We also used scree plots for that purpose; the point of strong inflection in a scree plot is regarded as a cut off for the number of factors extracted (Rosenblad, 2009). We excluded missing cases list-wise. We conducted multiple analyses before the final analysis, with the aim of obtaining a simple structure, in which each variable loaded highly onto one factor only. Finally, we performed a reliability analysis using Cronbach's Alpha on each factor identified by the main analysis.

Results

Table 1 shows the descriptive data of scores participants obtained on all performed tests. The average total score on BOTMP-2 short form was 75.6 (*SD* =4.4). We performed the factor analysis only on the raw test scores, and we excluded the following items because very little or no variability (ceiling effect) might would have hindered the function of the correlation matrix (Rosenblad, 2009): "jumping synch," "tapping hand and foot synchronised," and "walking forward in a line." We then ran a preliminary analysis, eliminating the VO_{2max} score as it did not correlate with any other variables.

We conducted a first principal factor analysis on the remaining test scores (16 items) with oblique rotation (direct oblimin, Table 2). The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis (KMO = 0.67), which corresponded to "Mediocre;" and all KMO values of individual items were larger than the acceptable level of 0.5 (except for ball dribbling: 0.416). The resulting scree plot as well as the eigenvalues suggested the extraction of five factors. The results of this analysis led to the exclusion of two items: "ball dropping and catching" and "ball dribbling" for several reasons. First, both items failed to correlate highly with any of the other variables in the correlation matrix. Second, the item "ball dropping and catching" did not load on any of the factors after rotation, and the KMO value of the "ball dribbling" was below the acceptable level of 0.5. Finally, both items were at extreme risk for a ceiling effect.

Next, we conducted a second principal factor analysis on the 14 remaining items with oblique rotation (direct oblimin, Table 2). The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis (KMO= 0.7), which corresponded to "Meddling;" and all KMO values of individual items were larger than 0.66 which is well above the acceptable level of 0.5. We ran an initial analysis to obtain eigenvalues for each factor in the data. Four factors had eigenvalues over Kaiser's criterion of 1 and in combination explained 45% of the variation. The scree plot suggested the extraction of four factors or latent variables (Figure 1). The first factor comprised the shuttle run, broad jump, ball wall toss and sit-ups tests and could therefore be labelled "gross motor skills and power." The second factor included the items copying star, following the maze and paper folding; hence we named it "fine motor skills." The third latent variable was comprised of push-ups, hopping and balance beam and was labelled "core strength and balance," and, finally, the fourth factor included the medicine ball throw and handgrip and so was named "general body strength." Results from the reliability analysis are presented in Table 3.

Discussion

The main finding of this study shows that our selection of motor proficiency and fitness tests, when used with 13-14 year old adolescents, can be grouped into a four-factor structure of (a) gross motor skills and power, (b) fine motor skills, (c) core strength and balance, and (d) general body strength. These categories could be particularly useful when trying to reduce motor proficiency test items for large scale screening in schools. The following paragraph will discuss which test items would be most relevant in each of these four categories.

Before discussing the latent variables identified by our analysis, it is important to consider the excluded items. Three items of the BOTMP-2 short form were excluded before running the analysis for having very little to no variability. This finding is similar to reports by Brahler et al. (2012) who characterised multiple BOTMP-2 short form items as showing no variability and as being highly susceptible to a ceiling effect. The VO_{2max} scores obtained from the CST were also excluded for having no correlation with any other test items for two possible reasons. First, cardiovascular fitness might be a stand-alone ability that shares no common features with other motor skills. However, this is very unlikely in light of vast literature describing a clear relationship between coordination, motor proficiency and fitness (Barnett et al., 2009; Haga, 2009; Rivilis et al., 2011). A second and more plausible explanation is that the CST did not yield reliableVO_{2max} measures, possibly because the short duration for obtaining these measurements (10 second rest between stages) together with the slow recording of HR data by the pulse oximeters that meant that the student's heart rate (HR) would have already changed by the time it was measured. Also, this technology is not suitable in winter months, as pulse measurement from the fingers could not be obtained on occasions when participants' fingers were too cold to register it. With these challenges in mind, we suggest that CST is not a suitable test of cardiovascular fitness for mass screening. However, because of a well-established link between CST and life-threatening adult conditions like cardiovascular disease (Rivilis et al., 2011) and depression (Cairney et al., 2013), CST should be tested in school for these purposes. It should be replaced with a test that does not rely on HR measurement, such as the 20-m shuttle run.

We labelled the first latent factor revealed by our analysis "gross motor skills and power," and it included the shuttle-run test, broad jump, sit-ups and ball wall toss. This latent factor is similar to the group of factors identified by Kambas and Venetsanou (2014) in their examination of a motor screening tool (DEMOST-PRE) in pre-school children that these authors called "gross motor control," as it included a variety of jumping and running tests, as well as one upper body element (running and carrying and placing a ball in a box). Furthermore, an analysis of the BOTMP-2 in pre-school and primary school children also resulted in the classification of various tests into a "gross motor skill" ability, with tasks that included the broad jump and a speed and agility test, similar to tasks in our study (Kambas & Aggeloussis, 2006). The similarity between our findings and those of previous studies highlights that no matter the age group considered, gross motor skills are essential in the screening of children and adolescents for fitness or coordination purposes. Indeed, these skills form the basis of the games undertaken in play grounds, and poor competence in these skills could be a main cause of children's low physical activity levels (Barnett et al., 2009; Cairney et al., 2005). Within this first gross motor skill factor, the items that loaded the highest in the present study were the agility shuttle run and broad jump, with correlation coefficients of -.0778 and 0.628, respectively. In a test battery for fitness or coordination screenings in schools, these tests should be included. The broad jump test, is part of multiple motor proficiency batteries like the ALPHA health related fitness battery for children and the European test of Physical Fitness (EUROFIT, (Baquet et al., 2001; Ortega et al., 2008). When the question of using both or only one of these tests arises, different arguments could be put forward. In favor of using both tests, Salaj and Markovic (2011) showed that jumps, including the broad jump, and quick changes in direction, such as the agility shuttle-run, are two distinct abilities and should be tested separately. However, while both tests had acceptable reliability in our study, the Cronbach's Alpha when the shuttle run (0.355) was deleted was greater than the overall factor reliability (0.225). Thus, removing this item would improve the overall reliability of the factor. The shuttle run might not be the most meaningful for this factor. Consequently, we suggest using the broad jump as a more meaningful test for this factor. The sit-up test was also amongst the variables selected in this first factor. A very recent study (Brown, 2019) on the structural validity of the BOTMP-2 short form identified the sit-up test as one of the five crucial elements to keep in a revised version of this test, further highlighting its importance in testing fitness/coordination.

We labelled the second latent factor identified by our analysis "fine motor skills," and it was comprised of the maze, paper folding, copying star and copying square items. Fine motor skills are an essential component of coordination, and all batteries of tests for motor proficiency include this category (Bruininks, 2005; Henderson, Rose, & Henderson, 1992). Furthermore, similar to our findings, a recent study based on the factorial structure of the Movement Assessment Battery for Children, identified a group of similar items called "manual dexterity" (Psotta & Brom, 2016). The items included within this category corresponded to two subcategories of the BOTMP-2, namely fine motor precision (maze, folding paper) and fine motor integration (copying a star shape, copying a square shape (Bruininks, 2005), with the items related to fine motor precision loading highly on factor two in our analysis. This suggests that motor integration might be less important in this context. However, in practical terms, administering these two items was tricky as participants (especially boys) tended to lost patience with them and made an insufficient effort to perform them correctly. In contrast, the "copying" items were quicker to perform. We recommend the "copying" items for school screening as their sensitivity is greater in children and adolescents. Indeed, adolescents' shorter attention spans are exacerbated by indoor versus outdoor activities (Rogerson, Gladwell, Gallagher, & Barton, 2016). Further studies are needed for determining how this variable affects the sensitivity of tests performed in the context of indoor school screening. Our reliability analysis indicated that the “copying star” test would be a better choice, compared to the “copying square” test, because of its greater reliability (0.433 *vs.* 0.266) and its Cronbach’s Alpha If Item deleted (0.444) below the overall reliability of the factor (0.530), unlike the “copying square” test (0.602).

The third group of items revealed by our analysis included push-ups, hopping, balance beam, penny transfer and maze items. We labelled it “core strength and balance.” Several studies relying on reduction analysis included “balance” as a latent factor, whether they used the BOTMP-2 or other tests, such as the M-ABC (Hassan, 2001; Psotta & Brom, 2016). Balance was also identified as an important discriminating factor between children with poor coordination and children with good coordination (Hands, 2008). It is interesting to note that this group of test items is the most heterogenous of the four groups identified in the present study, with items such as penny tranfers or maze included, even though they did not reach the threshold of 0.5 that one would instinctively characterize as necessary for their inclusion among tests of fine motor skills. This observation, together with the fact the mazes item loaded on two factors, questions the separation between fine and gross motor skills, highlighted by Hassan (2001). Indeed, Hassan suggested that there is some moderate degree of factorial balance overlap between components of motor proficiency assessments, and that gross and fine motor skills should be considered on a continuum rather than as separate skills (Hassan, 2001). While push-ups loaded highly on this factor, when reflecting on the practical aspects of this test, we noticed that the technique required for performing it was difficult, particularly for participants who had not done push ups before the screening. As this observation affected the suitability of this test in the context of school screenings, we suggest that efficiency-minded examiners use another item, such as hopping, that also loaded highly on this factor. In favor of this choice, hopping was one of the five test items of the BOTMP-2 short form retained after a structural validity analysis (Brown, 2019). Our reliability analysis showed acceptable values for this test (reliability of 0.411 and Cronbach's Alpha If Item deleted (0.307) lower than the overall reliability of the factor (0.483)).

Finally, the last latent factor from our analysis included handgrip strength and medicine ball throw. Although these tests are performed with the upper limb, they are also associated with general coordination and strength (Luz et al., 2018; Wind et al., 2010). Hence, we named it "general strength." As both tests obtained a high loading score, the choice of only one test for this category might rely on the practical aspects associated with their use in mass screening. While the medicine ball test might be the cheapest option, the correct technique for it was quite difficult to judge. This test requires participants to "throw the medicine-ball vigorously as far straight forward as they could while maintaining their back against the wall," but there was no objective way to determine if the trajectory of the ball was horizontal and if participants' back remained against the wall. For this reason, we recommend using the handgrip strength test in school screening, even though it requires more equipment. This is a reliable test (0.617 in our study), and it is objective and easy to administer. It has also shown good predictive ability for total body strength, (Wind et al., 2010) and bone mineral density (Chan et al., 2008).

Although the"tennis ball wall toss" test (Du Toit et al., 2010) loaded on the first factor, suggesting that this factor may represent a gross motor skill, we believe it is important to include this test as a separate item. It is the only test that assessed eye hand coordination, highlighted as a fundamental aspect of motor proficiency in the BOTMP-2 (Antonis Kambas & Aggeloussis, 2006). In addition, Psotta and Brom (2016) noted that “aiming and catching,” was one of the three categories for the factorial structure of a test battery for motor proficiency. As this task has an obvious relationship to a great many sporting activities involving catching and throwing, it may be particularly predictive of later engagement in sports and PA generally.

The main limitations of this study were that our participants came from only one school and may not be representative of the overall British adolescent population. Indeed, factors such as academic performance, geographical location, socio-economical status and existing sports opportunities and success were restricted in this ample Further studies with more diverse populations are needed. In addition, we did not measure the maturational status of our participants, and it is likely that 13-14 years old boys and girls may be at different stages of maturation. Finally, we could not get information about our participants’ physical activity levels and/or sport participation, and data regarding these variables could help interpret our results.

Conclusion

In conclusion, our findings suggest that a relevant battery of tests to screen for fitness and coordination in school settings should assess four main factors: (a)gross motor skills and power, (b)nfine motor skills, (c) core strength and balance, and (d) general body strength. Tests of choice within these areas should be the broad jump, copying a star shape, hopping and handgrip strength. Future studies should assess the feasibility of large scale school screening using these tests and should evaluate their association to engagement in sports and PA at various subsequent ages during development.

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Table 1. Descriptive data of scores obtained on all performed tests.

Test Item	Mean	SD	Range
Height (cm)	161.7	9.2	101.0-187.0
Weight (kg)	50.7	9.6	32.9-84.9
BMI ($kg.m^{-2}$) boys	19.0	3.1	14.2-31.6
BMI (z score) boys	0.18	1.36	-1.98-5.77
BMI ($kg.m^{-2}$) girls	19.9	4.0	14.4-44.9
BMI (z score) girls	0.26	1.52	-1.83-9.86
Ball dropping and catching with two hands (number of successful attempts out of 5)	4.8	0.8	0-5
Ball dribbling with alternate hands (number of successful attempts out of 10)	9.4	1.7	1-10
Push-ups (number in 30 s)	22	7.6	4-50
Sit-ups (number in 30 s)	21	5.1	10-36
Balance beam (s, maximum 10 s)	8.2	2.9	1-10
Walking forward in a line (number of steps)	6.0	0.1	5-6
Penny transfer (number in 15 s)	16	2.2	7-20
Tapping-coordinated (number of successful attempts out of 10)	9.9	0.6	5-10
Jumping synch (number of successful attempts out of 5)	5.0	0.0	5-5
Hopping (number in 15 s)	40	7	7-58
Paper folding (s)	6.1	1.5	0-7
Copying star shape (s)	4.8	0.7	0-5
Copying square shape (s)	5.0	0.2	4-5
Maze (s)	6.8	1.0	0-7
Broad Jump (m)	1.6	0.3	0-3.1
Medicine ball throw (m)	3.5	0.8	1.3-6.4
Handgrip (kg)	25.6	6.3	9-48
Tennis wall Toss (catches in 15 s)	21	8	0-40
10 x 5-m shuttle-run (s)	19.9	2.2	14.7-29.4
VO_{2max} ($ml.kg^{-1}.min^{-1}$)	37.1	4.8	22.3-48.7

Balance beam: standing on one leg on a balance beam, eyes open; tapping coordinated: tapping feet and fingers same side synchronised; jumping synch: jumping in place same side synchronised; hopping: one-legged stationary hopping, maze: Drawing line through paths-crooked (s).

Table 2. Pattern matrix of the rotated factors (oblique rotation) for the initial and second analyses.

Test Item	**Factors initial analysis**				
	1	2	3	4	5
10 x 5m shuttle run	-.747				
Broad Jump	.563			.316	
Sit-ups	.562				
Ball dropping and catching					
Maze		.714	.355		
Paper folding	.403	-.608			
Copying star		-.528			
Copying square		-.425			
Push-ups			.600		
Hopping			.592		
Balance beam			.534		
Penny transfer			.356		
Medicine Ball				.832	
Handgrip				.806	
Ball dribbling					.655
Tennis wall toss	.369				.398

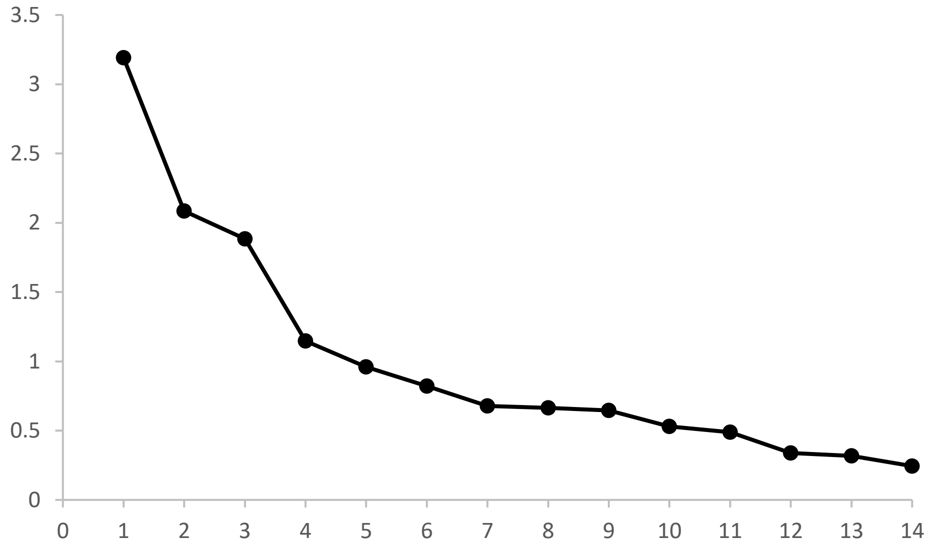
Test Item	**Factors second analysis**			
	1	2	3	4
10 x 5-m shuttle run	-.778			
Broad Jump	**.628**			
Sit-ups	.573			
Tennis wall Toss	.474			
Maze		.798	.307	
Paper folding		-.690		
Copying star		**-.445**		
Copying square		-.361		
Push-ups			.579	
Hopping			**.558**	
Balance beam			.549	
Penny transfer			.394	
Medicine ball				.799
Handgrip				**.789**

Table 3. Results of the reliability analysis on the factors identified by the second analysis.

	Corrected item-total correlation	Cronbach's Alpha if item deleted
Factor 1 Cronbach's Alpha = 0.225		
Shuttle run	-0.653	0.355
Broad Jump	0.336	0.058
Sit-ups	0.429	0.090
Tennis wall Toss	0.348	0.050
Factor 2 Cronbach's Alpha = 0.560		
Maze	0.521	0.331
Paper folding	0.422	0.515
Copying star	0.433	0.444
Copying square	0.266	0.602
Factor 3 Cronbach's Alpha = 0.483		
Maze	0.101	0.508
Push-ups	0.387	0.334
Hopping	0.411	0.307
Balance beam	0.395	0.400
Penny transfer	0.226	0.471
Factor 4 Cronbach's Alpha = 0.263		
Medicine ball	0.617	-
Handgrip	0.617	-

Figure 1. Scree plot of the second factor analysis. The inflection point suggested the extraction of four factors.

Eigenvalue



Factor number