Journal of Science and Medicine in Sport xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

The Athletic Skills Track: Age- and gender-related normative values of a motor skills test for 4- to 12-year-old children

J.J.A.A.M. Hoeboer[a,*], G. Ongena[b,c], M. Krijger-Hombergen[a], E. Stolk[a], G.J.P. Savelsbergh[d], S.I. de Vries[a]

[a] Research Group Healthy Lifestyle in a Supporting Environment, Faculty of Health, Nutrition & Sport, The Hague University of Applied Sciences, The Netherlands
[b] Department Institute for ICT, HU University of Applied Sciences, The Netherlands
[c] Department of Information Technology and Services, The Netherlands
[d] Department of Human Movement Sciences, Faculty of Behavioural and Human Movement Science, VU University Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 16 November 2017
Received in revised form 21 January 2018
Accepted 26 January 2018
Available online xxx

Keywords:
Physical education
Child
Motor skills
Physical activity
Motor competence test

ABSTRACT

Objectives: The aim of the presented study is to provide age- and gender-related normative values and MQ values for a motor skills test, the Athletic Skills Track, among 4- to 12-year-old children.
Design: Cross-sectional.
Methods: In 2016, a total of 7977 Dutch children, 4036 boys (mean age 8.6 years, SD 2.1) and 3941 girls (mean age 8.6 years, SD 2.1), performed an age-related version of the Athletic Skills Track (AST). The AST is a track consisting of 5–7 fundamental movement skill tasks that should be completed as fast as possible. The children performed the test during a regular physical education (PE) lesson under the supervision of their own PE teacher. For each version of the AST (AST-1: n = 917; AST-2: n = 3947; AST-3: n = 3213) age- and gender-related reference centiles were derived from the gathered data using the Lambda, Mu, Sigma (LMS) method.
Results: All children completed the AST within 60 s (mean 29.6 s, SD 7.7). An independent samples t-test showed that boys were significantly faster in completing the track than girls, except for the 4-year-old boys. Therefore, age- and gender-related reference centiles were derived. The reference curves demonstrate an almost linear decrease in time to complete AST-1 and AST-2 with increasing age.
Conclusions: The present study provides age- and gender-related normative values and MQ values for the AST among 4- to 12-year-old Dutch children. With these normative values PE teachers can interpret children's performance on the AST.

1. Introduction

Physical literacy (PL) is gaining more and more attention in physical education (PE), physical activity (PA) and sports promotion worldwide. PL is the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life.[1] PE is an important resource to develop PL during childhood.[2,3] A high level of motor skill competence in youth is associated with several health related parameters such as lower body mass index,[4,5] better cardiorespiratory fitness,[6] and higher PA levels in cross-sectional[7–9] and longitudinal studies.[10] Motor skill competence is constrained by the level of fundamental movement skills (FMS) performance.[11] FMS are associated with increased cognitive development,[12,13] social development and language skills.[14] Furthermore, good FMS performance is positively associated with self-esteem[15] and reduced levels of anxiety.[16]

The crucial development of FMS is inbedded in the development of motor skill competence as shown in the mountain of motor development.[17] Although motor skill development is a nonlinear, self-organizing process that is driven by task, environment and organism,[18] this metaphor of motor development shows six periods of development that characterizes most typically developing individuals.[17]

Since children's FMS and PA levels seem to have decreased in the last decades,[19] there is an urgency to increase our understanding of the development of FMS and to develop effective strategies to support children in obtaining an optimal level of PL. Therefore, we

* Corresponding author.
E-mail address: j.j.a.a.hoeboer@hhs.nl (J.J.A.A.M. Hoeboer).

https://doi.org/10.1016/j.jsams.2018.01.014
1440-2440/

need valid motor skill competence tests. The urgency to increase our understanding of motor skill development is also recognised by PE teachers who are willing to monitor motor skill competence of children more objectively.[20]

In 2016, researchers[21] have developed a robust and feasible motor skill competence test, the Athletic Skills Track (AST) that PE teachers can use to assess children's FMS in an objective way. The AST is fundamentally different than conventional motor competence tests. The AST is a track that consists of a series of 5–7 detached, rather than isolated, FMS based on coordinative abilities[22] (e.g. coupling, spatial orientation, and balance ability).[23,24] Previous studies have shown that the AST is a reliable, valid and feasible assessment tool to assess FMS among children from 4 to 12 years old in the PE setting.[21,25] In the first study, it was shown that it was possible to measure one class of approximately 24 children in a one hour lesson. All children completed the track within 60 s. The concurrent validity of the AST was moderate to high; i.e., the correlation coefficient between the time to complete the AST and age- and gender-specific motor quotients of the Körperkoordination-Test für Kinder (KTK) ranged between $r = -0.469$ and $r = -0.767$ ($p < 0.05$).[21] In the second study three age-related versions of AST have been developed. AST-1 has been developed for 4- to 6-year-old children, AST-2 for 6- to 9-year-old children and AST-3 for 9- to 12-year-old children. The test-retest reliability of the AST proved to be high (AST-1: ICC = 0.881, AST-2: ICC = 0.802, AST-3: ICC = 0.800). The internal consistency was above the acceptable level of Cronbach's $\alpha > 0.70$ (AST-1 = 0.764, AST-2 = 0.700, AST-3 = 0.763). The concurrent validity between the AST and the KTK were even higher than in the first study (AST-1: $r = -0.747$, $p = 0.01$; AST-2: $r = -0.646$, $p = 0.01$; and AST-3: $r = -0.602$, $p = 0.01$).[25]

Although the AST appears to be a promising objective tool to assess children's motor skill competence in the PE setting, the lack of normative values limits the ability to interpret children's performance on the AST. Producing reference norms and Motor Quotient (MQ) outcomes generates a scoring system that describes individuals global motor competence in meaningful categories, and allows comparison with results from other schools, region, countries and studies.[26] Therefore, the objective of the presented cross-sectional study was to provide age- and gender-related normative values and MQ values for the AST for Dutch children from 4 to 12 years old.

2. Method

The research design was set up to reach a large group of children. Children aged 4- to 12-years were recruited from 86 primary schools in The Hague region, the Netherlands. Informed consent was obtained from the parents or guardians of the children after they were given written information about the purpose and nature of the study. After the informed consent was obtained, 8,458 children completed an age-specific version of the Athletic Skills Track (AST-1, AST-2 or AST-3) under the supervision of their own PE teacher.

The age-specific versions of the AST consist of a series of fundamental movement skill tasks (AST-1: n = 5, AST-2: n = 7, and AST-3: n = 7) to be completed as fast as possible (see Supplementary material — Maps of AST-1, AST-2 and AST-3).[20] The only outcome measurement is time to complete the track. In all three tracks the same FMS are tested, with the difficulty of the tasks ascending from AST-1 over AST-2 to AST-3. The AST was completed during a regular PE lesson between March and April 2016. In this lesson the measurement was conducted in a gymnasium that was separated into three sections (see Supplementary material — Map of the gymnasium into three sections). In two sections the children received an autonomous assignment from their PE teacher. In the third part the AST was conducted. The PE teacher performed the track once after which the children performed three try-out trials. After having received feedback from the PE teacher during the three try-out trials the children performed one measurement trial independently. The PE teacher measured the time to complete the track using a stopwatch and registered it in Excel.

All 86 PE teachers who participated in this study were trained according to the AST protocol by the principal investigator of this study. The protocol provides guidelines about the AST to be used per age group. It also provides guidelines about how to deal with adverse events, such as falling or cheating. The study protocol was approved by the Ethical Committee of the Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands (ECB 2015–31).

Data analysis was performed with the Statistical Package for the Social Sciences (SPSS version 24.0, 64-bits edition, SPSS Inc, Chicago, Illinois). Of the 8458 children who were allowed by their parents or guardians to participate in the study, 7977 children met the inclusion criteria for data analysis (age: between 4 and 12 years; all data complete: Age, Gender, AST-track number and AST-time).

All data were expressed as Mean, Standard Deviation (SD), and range. The normality of the data was investigated by analysing the normal distribution in relation to the medians. In addition, histograms were plotted. Differences between boys and girls were examined per track with independent samples t-tests and with a one-way ANOVA it was investigated if the tracks were able to distinguish between age groups within the track.

Age- and gender-related reference centiles were derived per track using the Lambda, Mu, Sigma (LMS) method as introduced by Cole[27] using R GAMLSS packages.

Based on the reference centiles of the AST, MQ values were calculated following the example of the Körperkoordination-Test für Kinder (KTK).[28] The MQ (mean = 100; SD = ±15) gives an indication of children's level of motor giftedness, ranging from "gifted children" to "children with motor dysfunctions".[28] The norms for the MQ of the KTK are based on the performance of 1228 normally developing German children (1974). The MQ score is standardized by age and gender. As stated by Kiphard and Schilling[28] in a normal population, a MQ score below 85 represents a motor performance level that is considered as problematic. The normalised value was scaled with 100 as the average value based on the 50th percentile. The other cut-off points are based on the 10th, 25th, 75th, 90th percentiles using the following formula: MQ = (50th percentile AST-x/time AST-x) × 100.

3. Results

The final sample consisted of 7977 4- to 12-year old children (4036 boys and 3941 girls). The mean age of the boys was 8.6 years (SD 2.1) and the mean age of the girls was 8.6 years (SD 2.1). The Supplementary material — Descriptive statistics of respondents' characteristics, provides descriptive statistics of the final sample as well as the Dutch population (Central Dutch Foundation for Statistics [CBS]).[29] In our sample, the ratio of boys to girls was approximately equal, which does not significantly deviate from the Dutch youth population. Considering age, the sample does not fully reflect the Dutch population in the lower age group. This is because not all primary schools in The Netherlands provide PE lessons for children at the ages of 4 and 5 years. Hence, we consider the sample to be representative for Dutch children attaining PE lessons in terms of gender and age.

As shown in Table 1 all children completed the AST within 60 s. On average, boys completed AST-1 in 25.3 s ± 7.1, AST-2 in 30.6 s ± 7.3, and AST-3 in 27.0 s ± 6.9. Girls completed AST-1 in 27.4 ± 7.9 s, AST-2 in 33.0 s ± 7.9, and AST-3 in 29.1 s ± 6.8.

Please cite this article in press as: Hoeboer JJAAM, et al. The Athletic Skills Track: Age- and gender-related normative values of a motor skills test for 4- to 12-year-old children. *J Sci Med Sport* (2018), https://doi.org/10.1016/j.jsams.2018.01.014

Table 1
Descriptive statistics for each group of participants.

Track	N	Mean	(±SD)	95% CI	
				Lower	Upper
AST-1, Boys, age 4	78	32.3	(7.6)	30.6	34.0
AST-1, Boys, age 5	200	25.3	(7.0)	24.4	26.3
AST-1, Boys, age 6	199	22.6	(5.0)	21.9	23.3
AST-1, Boys, total	**477**	**25.3**	**(7.1)**	**24.7**	**26.0**
AST-1, Girls age 4	93	34.2	(8.8)	32.4	35.9
AST-1, Girls age 5	171	27.1	(7.1)	26.1	28.2
AST-1, Girls, age 6	176	24.0	(5.4)	23.2	24.8
AST-1, Girls, total	**440**	**27.4**	**(7.9)**	**26.6**	**28.1**
AST-2, Boys, age 6	222	34.6	(7.3)	33.6	35.6
AST-2, Boys, age 7	630	32.5	(7.3)	31.9	33.1
AST-2, Boys, age 8	633	29.6	(7.0)	29.1	30.1
AST-2, Boys, age 9	485	27.4	(5.8)	26.9	27.9
AST-2, Boys, total	**1970**	**30.6**	**(7.3)**	**30.2**	**30.9**
AST-2, Girls, age 6	235	38.4	(8.0)	37.4	39.4
AST-2, Girls, age 7	636	35.1	(7.8)	34.5	35.8
AST-2, Girls, age 8	622	30.9	(6.7)	30.4	31.4
AST-2, Girls, age 9	384	29.7	(6.7)	29.0	30.3
AST-2, Girls, total	**1877**	**33.0**	**(7.9)**	**32.7**	**33.4**
AST-3, Boys, age 9	140	27.1	(5.9)	26.1	28.1
AST-3, Boys, age 10	506	27.5	(6.7)	27.0	28.1
AST-3, Boys, age 11	510	27.3	(7.4)	26.7	28.0
AST-3, Boys, age 12	433	25.9	(6.5)	25.2	26.5
AST-3, Boys, total	**1589**	**27.0**	**(6.9)**	**26.6**	**27.3**
AST-3, Girls, age 9	163	29.4	(6.2)	28.5	30.4
AST-3, Girls, age 10	500	30.4	(7.0)	29.8	31.0
AST-3, Girls, age 11	535	28.7	(6.9)	28.2	29.3
AST-3, Girls, age 12	426	28.0	(6.6)	27.3	28.6
AST-3, Girls, total	**1624**	**29.1**	**(6.8)**	**28.8**	**29.5**

AST-1 = Athletic Skills Track-1, AST-2 = Athletic Skills Track-2 and AST-3 = Athletic Skills Track-3.

Table 2
Results of an independent-samples t-test between boys and girls.

Track	Boys	Girls	T	P
AST-1, age 4	32.3 (±7.6) (N = 78)	34.2 (±8.8) (N = 93)	−1.457	0.147
AST-1, age 5	25.3 (±6.9) (N = 200)	27.1 (±7.1) (N = 171)	−2.457	0.014*
AST-1, age 6	22.6 (±5.0) (N = 199)	24.0 (±5.4) (N = 176)	−2.642	0.009*
AST-2, age 6	34.6 (±7.3) (N = 222)	38.4 (±8.0) (N = 235)	−5.261	0.000*
AST-2, age 7	32.5 (±7.3) (N = 630)	35.1 (±7.8) (N = 636)	−6.236	0.000*
AST-2, age 8	29.6 (±7.0) (N = 633)	30.9 (±6.7) (N = 622)	−3.388	0.001*
AST-2, age 9	27.4 (±5.8) (N = 485)	29.7 (±6.7) (N = 384)	−5.147	0.000*
AST-3, age 9	27.1 (±5.9) (N = 140)	29.4 (±6.1) (N = 163)	−3.260	0.001*
AST-3, age 10	27.6 (± 6.7) (N = 506)	30.7 (± 7.0) (N = 500)	−6.532	0.000*
AST-3, age 11	27.3 (±7.4) (N = 510)	28.7 (±6.7) (N = 535)	−3.278	0.001*
AST-3, age 12	25.9 (±6.6) (N = 433)	28.0 (±6.6) (N = 426)	−4.791	0.000*

AST-1 = Athletic Skills Track-1, AST-2 = Athletic Skills Track-2 and AST-3 = Athletic Skills Track-3.
* Correlation is significant at the 0.05 level.

An independent samples t-test showed a significant difference between boys and girls in time to complete the track (see Table 2). Boys were significantly faster than girls (on average between 1.3 up to 3.8 s), except for the 4-year-olds on AST-1.

A one-way ANOVA revealed that, both for boys and for girls, the tracks were able to distinguish between age groups within the track. The time scores on AST-1, AST-2 and AST-3 were significantly different between the age groups (AST-1 girls: Welch's F (65.412) = 3138.491, P < 0.01; AST-2 girls: Welch's F (105.520) = 5596.357, P < 0.01; AST-3 girls: Welch's F (10.702) = 485.279, P < 0.01; AST-1 boys: Welch's F (65.685) = 2639.745, P < 0.01; AST-2 boys: Welch's F (80.036) = 3782.352, P < 0.01; AST-3 boys: Welch's F (5.634) = 262.541, P < 0.01). Bonferroni post hoc analysis revealed that the differences between the age groups within a track were all significant (P < 0.01) except for the difference between some age groups for AST-3 (AST-3 girls: mean difference 9–10 year olds: −1.002 s, 95% CI: −2.606 to 0.603; mean difference 9–11 year olds: 0.673 s, 95% CI: −0.919 to 2.264; mean difference 9–12 year olds: 1.409 s, 95% CI: −0.233 to 3.043; mean difference 11–12 year olds: 0.732 s, 95% CI: −0.423 to 1.887; and AST-3 boys: mean difference 9–10 year olds: −0.448 s, 95% CI: −2.170 to 1.274; mean difference 9–11 year olds: −0.182 s, 95% CI: −1.902 to 1.539; mean difference 9–12 year olds: 1.274 s, 95% CI: −0.479 to 3.028; mean difference 10–11 year olds: 0.266 s, 95% CI: −0.865 to 1.398).

As can be seen in Table 2, the results of 6-year olds on AST-1 cannot be compared with the time of (other) 6-year old children to complete AST-2. It took 6-year-old boys 34.6 ± 7.3 s to complete AST-2 compared to 22.6 ± 5.0 s for AST-1. Similar findings are shown for girls. In the transition period between AST-2 and AST-3 smaller differences are found. The 9-year-old boys and girls needed more or less the same time to complete AST-2 compared to AST-3 (boys: 27.4 ± 5.8 versus 27.1 ± 5.9 s for AST-2 and AST-3 respectively; girls: 29.7 ± 6.7 versus 29.4 ± 6.2 s for AST-2 and AST-3 respectively).

Based on the significant differences between boys and girls, reference centiles were calculated per gender and track using the Lambda, Mu, Sigma (LMS) method[27] based on the 10th, 25th, 50th, 75th and 90th percentile. As shown in Fig. 1a and b the reference curves demonstrate an almost linear decrease in time to complete AST-1 and AST-2 with increasing age for boys and girls. The time to complete AST-3 remains relatively stable among 9- to 12-year-old boys and girls (see Fig. 1c).

To ease the interpretation of the outcomes of the AST the reference curves have been converted into MQ values (Supplementary material — MQ values for five categories of motor giftedness). With the formula MQ = (50th percentile AST-x/time AST-x) × 100 and the table PE teachers can calculate and interpret each child's MQ value based on the time to complete the track, the 50th percentile of the track, the age and the gender of the child. For example, a 7-year-old boy finishes AST-2 in 29.5 s. The MQ of this boy is: MQ = 31.4 (50th percentile of AST-2)/29.5 s (time of the boy to complete AST-2) × 100 = MQ = 31.4/29.5 × 100 = 106. This child is normally motor gifted since his MQ value lies between 87 and 116 (see Supplementary material — MQ values for five categories of motor giftedness).

4. Discussion

In this study age- and gender-related normative values have been developed based on the time to complete AST-1, AST-2 and AST-3 for children in the age of 4- to 12-years old.

The results show that boys are significantly faster on all the tracks except for the 4-year-old boys (boys: 32.3 ± 7.6 s versus girls: 34.2 ± 8.8 s; t = −1.457, p = 0.147). The gender difference that we have found is in line with other motor competence tests such as the KTK.[28]

Besides gender differences, age differences have been found as well. As shown in the reference curves an almost linear decrease in time to complete AST-1 and AST-2 can be seen with increasing age. The time to complete AST-3 remains relatively stable among 9- to 12-year-old boys and girls. This phenomenon is in line with

Please cite this article in press as: Hoeboer JJAAM, et al. The Athletic Skills Track: Age- and gender-related normative values of a motor skills test for 4- to 12-year-old children. *J Sci Med Sport* (2018), https://doi.org/10.1016/j.jsams.2018.01.014

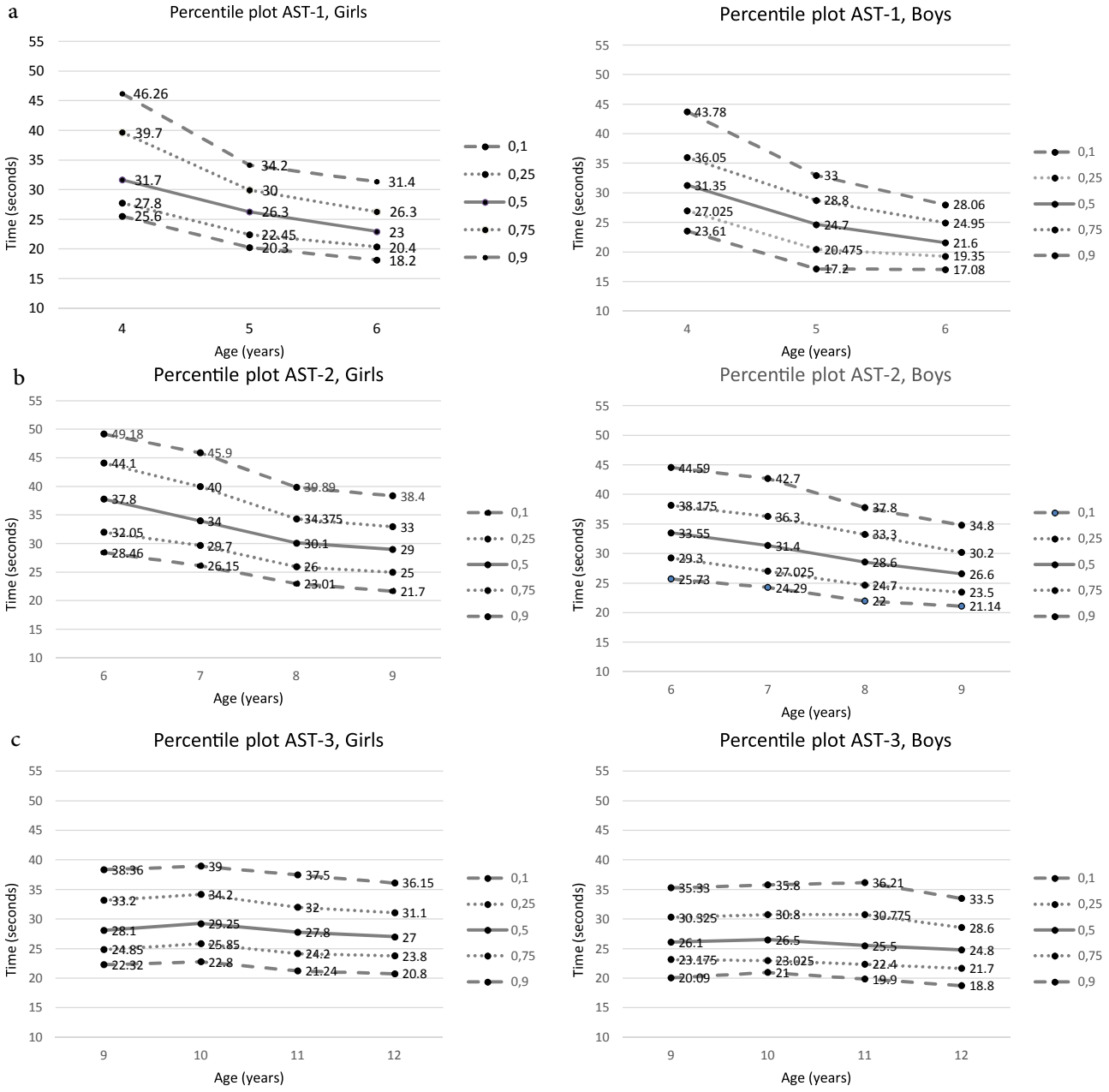

Fig. 1. (a) Gender specific percentile plots for AST-1. The percentile plots are based on the 10th–25th–50th–75th–90th percentile (AST-1 = Athletic Skills Track-1). (b) Gender specific percentile plots for AST-2. The percentile plots are based on the 10th–25th–50th–75th–90th percentile (AST-2 = Athletic Skills Track-2). (c) Gender specific percentile plots for AST-3. The percentile plots are based on the 10th–25th–50th–75th–90th percentile (AST-3 = Athletic Skills Track-3).

the theoretical metaphor: "the mountain of motor development" developed by Clark and Metcalfe.[17] This metaphor of motor development charactarizes most typically developing individuals in six periods.[17] In the fundamental patterns period, fundamental motor skills are further elaborated into the building blocks of later context specific motor skills. This fundamental patterns period lasts for most children until the age of 7–8 years old.[17] The development of the fundamental movement skills in this period can be seen in the reference centiles of AST-1 and AST-2 as these children are in the age of developing those fundamental building blocks. The relatively stable line of the reference centiles of AST-3 can be explained by the fact that the children are at the end of the fundamental pattern period and at the beginning of the following, context-specific, period. This can also explain the lack of difference in the time to complete AST-2 and AST-3 for 9-year old children. Nine-year-old boys and girls needed approximately the same time to complete AST-2 as AST-3 (AST-2: boys: 27.4 ± 5.8 s, girls: 29.7 ± 6.7 s versus AST-3: boys: 27.1 ± 5.9 s, girls: 29.4 ± 6.2 s). In this context-specific period children have established their basic motor repertoire and they begin to apply the fundamental patterns towards a variety of tasks and environmental contexts.[17] The transitions between AST-1, AST-2 and AST-3 shows that the 6-year-old boys (22.6 ± 5.0) and girls (24.0 ± 5.4) on AST-1 are faster than the 6-year-old boys (34.6 ± 7.3) and girls (38.4 ± 8.0) on AST-2. This is in line with the fact that AST-1 consists of 5 skills and AST-2 of 7 skills.

Besides reference curves based on time to complete the tracks, MQ values have been calculated for the AST. This eases the interpretation of AST outcomes in daily PE practice. The development of MQ values can be seen as a scoring system that classifies individual scores into meaningful global categories, and allows comparison with results from other studies.[26]

Please cite this article in press as: Hoeboer JJAAM, et al. The Athletic Skills Track: Age- and gender-related normative values of a motor skills test for 4- to 12-year-old children. *J Sci Med Sport* (2018), https://doi.org/10.1016/j.jsams.2018.01.014

According to the classification of Kiphard and Schilling,[28] children with an MQ value between 86 and 115 are considered as having normal gross motor coordination, children scoring between 71 and 85 as having a moderate gross motor coordination disorder and children scoring 70 or less as having a severe gross motor coordination disorder. Children scoring between 116 and 130 are considered as having good motor coordination and children scoring above 130 as having a high motor coordination.

Based on the reference centiles in this study approximately the same cut-off points are found for AST-1, AST-2 and AST-3. These findings are in line with the study on the reference values of the KTK.[3]

This study has some limitations. First, the participants of this study are all children in the The Hague region. This might have influenced the normative values presented because the data was collected within the urbanity of The Hague. A sub-urban population might show other results.

Secondly, the data was collected among a sample of children who all received 2 PE lessons per week by qualified PE teachers. In other parts of the Netherlands this is not the case. On average, 54% of the primary school in the Netherlands have a qualified PE teacher to provide the PE lessons.[30] This might have influenced the results because children who receive PE lessons from a qualified PE teacher might have better motor skills. In future studies it could be interesting to examine the reference centiles in other regions of the Netherlands or other countries.

Thirdly, the reference curves presented in this study are based on the age in years. This means that all children with the same birth year are presented in the reference curves as the same age. It would be more precise if the reference curves are based on the year and month of birth.

5. Conclusion

In conclusion, the AST is a reliable, valid and feasible assessment tool to assess FMS among children from 4 to 12 in the PE setting.[21,25] With the presented age- and gender-related normative values and MQ values for the AST PE teachers can compare the motor skill competence of individual children with the motor skill competence of their peers or with their previous scores. In addition, the motor skill competence of groups of children, schools, neighbourhoods, regions, and even countries can be compared to the presented age- and gender-related normative values.

Practical implications

- PE teachers can use the AST to assess FMS of 4- to 12-year old children in the PE setting.
- PE teachers can use the AST normative values to interpret the level of motor competence of individual children and groups of children.
- The MQ values eases the interpretation of AST outcomes in daily PE practice.

Acknowledgement

This work was supported by a grant. The corresponding author is currently receiving a PhD-grant for teachers from The Dutch National Science Organization (NWO) (9023.006.005).

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jsams.2018.01.014.

References

1. Whitehead M. Definition of physical literacy and clarification of related issues. *ICSSPE Bull* 2013; 65(1.2).
2. Cools W, De Martelaer K, Samaey C et al. Movement skill assessment of typically developing preschool children: a review of seven movement skill assessment tools. *J Sports Sci Med* 2009; 8(2):154–168.
3. Vandorpe B, Vandendriessche J, Lefevre J et al. The KörperkoordinationsTest für kinder: reference values and suitability for 6–12-year-old children in flanders. *Scand J Med Sci Sports* 2011; 21(3):378–388.
4. Okely AD, Booth ML, Chey T. Relationships between body composition and fundamental movement skills among children and adolescents. *Res Q Exerc Sport* 2004; 75(3):238–247.
5. D'Hondt V, Deforche B, Vaeyens R et al. Gross motor coordination in relation to weight status and age in 5- to 12-year-old boys and girls: a cross-sectional study. *Int J Pediatr Obes* 2011; 6(Suppl. 3):e556–e564.
6. Okely AD, Booth ML, Patterson JW. Relationship of cardiorespiratory endurance to fundamental movement skill proficiency among adolescents. *PES* 2010; 13(4).
7. Logan SW, Robinson LE, Getchell N et al. Relationship between motor competence and physical activity: a systematic review. *Res Q Exerc Sport* 2014; 85(S1):A14.
8. Lubans DR, Morgan PJ, Cliff DP et al. Fundamental movement skills in children and adolescents. *Sports Med* 2010; 40(12):1019–1035.
9. Wrotniak BH, Epstein LH, Dorn JM et al. The relationship between motor proficiency and physical activity in children. *Pediatrics* 2006; 118(6):e1758–65.
10. Lloyd M, Saunders TJ, Bremer E et al. Long-term importance of fundamental motor skills: a 20-year follow-up study. *Adapt Phys Act Q* 2014; 31(1):67–78.
11. Veldman SL, Jones RA, Okely AD. Efficacy of gross motor skill interventions in young children: an updated systematic review. *BMJ Open Sport Exerc Med* 2016; 2(1):e000067.
12. Best JR. Effects of physical activity on children's executive function: contributions of experimental research on aerobic exercise. *Dev Rev* 2010; 30(4):331–351.
13. Hillman CH, Erickson KI, Hatfield BD. Run for your life! Childhood physical activity effects on brain and cognition. *Kinesiol Rev* 2017; 6(1):12–21.
14. Leonard HC, Hill EL. Review: the impact of motor development on typical and atypical social cognition and language: a systematic review. *Child Adolesc Ment Health* 2014; 19(3):163–170.
15. Piek JP, Baynam GB, Barrett NC. The relationship between fine and gross motor ability, self-perceptions and self-worth in children and adolescents. *Hum Mov Sci* 2006; 25(1):65–75.
16. Skinner RA, Piek JP. Psychosocial implications of poor motor coordination in children and adolescents. *Hum Mov Sci* 2001; 20(1):73–94.
17. Clark JE, Metcalfe JS. The mountain of motor development: a metaphor. *Mot Dev Res Rev* 2002; 2:163–190.
18. Newell KM. Constraints on the development of coordination, in *Motor Development in Children: Aspects of Coordination and Control*, Wade MG, Whiting HTA, editors, The Netherlands, Martinus Nijhoff, Dordrecht, 1986, p. 341–360 https://doi.org/10.1007/978-94-009-4460-2_19.
19. Hallal PC, Andersen LB, Bull FC et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet (London, England)* 2012; 380(9838):247–257.
20. Lander N, Morgan PJ, Salmon J et al. Teachers' perceptions of a fundamental movement skill (FMS) assessment battery in a school setting. *Meas Phys Educ Exerc Sci* 2016; 20(1):50–62.
21. Hoeboer J, De Vries S, Krijger-Hombergen M et al. Validity of an athletic skills track among 6- to 12-year-old children. *J Sports Sci* 2016:1–11.
22. Wormhoudt R, Teunissen JW, Savelsbergh GJ. *Athletic skills model*, Nieuwegein, Arko Sports Media, 2012.
23. Rudd JR, Barnett LM, Butson ML et al. Fundamental movement skills are more than run, throw and catch: the role of stability skills. *PLoS One* 2015; 10(10):e0140224.
24. Tidén A, Lundqvist C, Nyberg M. Development and initial validation of the NyTid test: a movement assessment tool for compulsory school pupils. *Meas Phys Educ Exerc Sci* 2015; 19(1):34–43.
25. Hoeboer J, Krijger-Hombergen M, Savelsbergh GJP et al. Reliability and concurrent validity of a motor skill competence test among 4- to 12-year old children. *J Sports Sci* 2017:1–7.
26. Toftegaard-Stoeckel J, Groenfeldt V, Andersen LB. Children's self-perceived bodily competencies and associations with motor skills, body mass index, teachers' evaluations, and parents' concerns. *J Sports Sci* 2010; 28(12):1369–1375.
27. Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalized likelihood. *Stat Med* 1992; 11(10):1305–1319.
28. Kiphard EJ, Schilling F. *Körperkoordinationstest für kinder: KTK*, Beltz-Test, 2007.
29. CBS Statline. Population dynamics: birth death and migration per region. http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLEN&PA=37259eng&LA=EN. Updated 2017 [Accessed 8 October 2016].
30. Reijgersberg N, Lucassen J. *Nulmeting bewegingsonderwijs: onderzoek naar de organisatie van het bewegingsonderwijs in het primair onderwijs*, Mulier Instituut, 2013.

Please cite this article in press as: Hoeboer JJAAM, et al. The Athletic Skills Track: Age- and gender-related normative values of a motor skills test for 4- to 12-year-old children. *J Sci Med Sport* (2018), https://doi.org/10.1016/j.jsams.2018.01.014